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DO YOU KNOW . . . .

► . . . . That the paragraph in the January JOURNAL regarding the number of second dues notices mailed in mid-November created considerable interest because it was thought to be a terrible situation? To keep you posted on dues collections, in February the third dues notice was sent to 947 individual members and ten institutional members. 232 of the Individual members were billed for two years' dues. Those who are two years in arrears and do not pay by early May will be sent a certified letter informing them of the arrearage and stating that they will be dropped from membership for non-payment of dues at the Annual Meeting if payment is not received by July 1, 1958. Last year third dues notices were sent to 996 individual and eleven institutional members, so some progress is being made. Early in the year it looked as though the dues payments were coming in considerably more promptly than a year ago, but such is not now the case. If *you* haven't paid up by now, please do so immediately.

► . . . . That individual memberships are still increasing rapidly? The goal of 1000 set last fall, is becoming a reality. It is encouraging to receive letters saying "here are nine applications for memberships." The Yearbook-Directory showed an increase in the number of individual memberships for the first time in three years, the total being 8057. Now, about a month before you read this, the total is 8424.

► . . . . That a new brochure has been prepared to entice industries to joint ASEE? Copies have been sent to all Deans of Engineering, and additional copies are available from Society Headquarters. There should be more industrial members, and each of you should be a salesman. If you have pushed as much as you can, refer your prospects to the Industrial Membership Committee. All who are engaged in placement activities have many good associations. Are you making the most of them?

► . . . . That the 1958 ASEE–AEC Summer Institutes received a fine response? The number attending Ames for Nuclear Metallurgy and Hanford for Chemical Processing could be greater, but all others are almost to capacity. The response from technical institute instructors was tremendous, about ten capable men having been turned down because capacity at Penn State-Argonne was thirty.

► . . . . That a fine series of evening programs has been arranged for the annual meeting in Berkeley? On Monday evening Dr. L. M. Gould, President of Carleton College, will speak on some of the activities of the Geophysical Year with which he has been associated. Entertainment and folk dancing, will follow, with swimming in the "gymnasium open air pool." On Tuesday evening is the ECAC–ECRC Annual Banquet with Dr. Simon Ramo speaking on "New Techniques in Education for the New Technical Era," followed by the reception honoring President and Mrs. F. C. Lindvall. On Wednesday a "salmon barbeque" at Tilden Regional Park! On Thursday evening comes the Annual Banquet and the presentation of awards. Each day will have a fitting climax.

► . . . . That it is rumored Newman Hall of Yale and R. G. Folsom of Rensselaer wanted to put on their ECPD accreditation skit in California,

in the hopes that the southern part of the state would send up some talent scouts? John Gammell, ASEE treasurer, their agent, is so convinced of their talent that he wants to see a second showing. John Rushton of Purdue is billed as the new talent. He is making his debut, convinced that he will be selected as the recipient of an Oscar. W. L. Everitt of the University of Illinois will be the barker, enticing one and all to come in and see for themselves the mysteries of ECPD accreditation! So, be at the General Session on Tuesday morning —see "A Case History of an Accreditation Team Visit For a Hypothetical Campus."

► . . . . That the speaker for the annual banquet will be Dr. Knowles Ryerson, Dean of the College of Agriculture of the University of California at Berkeley? He is the U. S. member of the South Pacific Commission and an authority on U. S. cooperation in the Pacific Basin. His talk will be on some phase of the activities of the United States in the South Pacific area.

► . . . . That the first regional EJC meeting definitely is scheduled for May 19 at Chicago's Sherman Hotel? The local host is the Western Society of Engineers (an EJC affiliate). The theme is "The Next Decade in Engineering."

► . . . . That the American Society of Mechanical Engineers has just announced that it will regularly translate into English the Russian bimonthly *Journal of Applied Mathematics and Mechanics*? Translation will be speeded by receiving proof sheets in advance of final printing. The project is financed by a grant of $35,000 from the National Science Foundation. The latest theoretical and practical advances made by Russian scientists in mathematics, fluid dynamics, and solid state physics are reported. Copies of the translated articles will be sold on a subscription basis at an annual rate of $35.00 for the six issues, but ASME members are entitled to a 20% discount. Subscriptions should be placed with the Order Department, The American Society of Mechanical Engineers, 29 West 39th Street, New York 18, New York.

► . . . . That the American Council on Education and Pennsylvania State University sponsored an invitational conference on teaching by television in colleges and universities in October of 1957? The full report of the proceedings will be published in the spring of 1958 by ACE. The program of the conference was developed on the assumption that the place of television as an instrument of teaching has been established. The question is not whether television shall be used for educational purposes, but rather how shall this medium best be used and for what purposes. Both closed-circuit and broadcast activities were considered. Among the major topics discussed were the potentialities and limitations of television as a means of teaching, a review of theories and principles of learning as applied to TV, a review of research relative to teaching by television, and practical problems of improving and assessing televised instruction.

The paper on "Education Philosophies in Television" by Dr. C. H. Faust, President of the Fund for the Advancement of Education, is published in full in the January 1958 Educational Record of ACE, and reprints are available upon request to the Council's Committee on Television.

W. Leighton Collins
Secretary

ASEE EMPHASIZES ROLE OF ENGINEERING

President Lindvall Sends Letter to Killian

THE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

February 3, 1958

Dr. James R. Killian, Jr.
Special Assistant to the President
The White House
Washington 25, D. C.

Dear Dr. Killian:

Without question increased support for teaching and research in Science and Engineering at all educational levels should be encouraged. It is also clear that many of our present difficulties in research, development, and practical utilization of new ideas are due to the fact that we need more engineers of high quality. This Engineering deficiency must be kept in sharp focus by specific identification in all measures, legislative and other, directed toward strengthening Science and Engineering.

The American Society for Engineering Education for many years has had as it primary objective the improvement of Engineering education. The key to this is faculties of high quality able to give the students the superior instruction which will prepare them for the problems of tomorrow of increasing complexity and scientific content. We have currently as the Society's number one project a Committee on the Development of Engineering Faculties.

This Committee concentrates attention on the needs of our Graduate Schools, which are the source of most of the new Engineering teachers to meet the growing demands both in quality and quantity. All possible encouragement and financial assistance should be given our most promising students to obtain graduate education in Engineering as rapidly as possible. At the same time, as a necessary part of healthy graduate work, the amount of research in the Engineering Sciences should be increased greatly. Research in the Engineering Sciences is particularly important as a part of the training of graduate students and for professional development of the Engineering faculties, and should be so recognized. Industry today can offer so many attractive possibilities for the young man interested in research and development, that without good Engineering research opportunities in our academic institutions few of our best young engineers will be attracted to teaching.

Your earnest consideration of the needs for graduate work and research in Engineering is most respectfully sought.

Sincerely yours,

F. C. LINDVALL,
President

IN SCIENTIFIC RESEARCH AND INSTRUCTION

ECAC Comments and Distributes Copies

In carrying further President Lindvall's effort to insure full recognition for Engineering in government support of science-technology research and graduate instruction, ECAC has distributed copies to its members for widespread use. Vice President Morgen's comments on the letter and problem are given below.

There seems to be a gross misunderstanding in Washington regarding the need for graduate education in engineering and what the engineering sciences are. It is very important that all members of ASEE and all members of the engineering profession do whatever is feasible to clarify this misunderstanding.

First, why graduate education in engineering and the need for more graduate students in engineering? The records show that over the past several years the number of Ph.D. degrees granted in engineering has been almost static at about 600 per year. Industry has been snapping up these graduates so thoroughly that there has been virtually no recruitment of new teaching staff in the various engineering departments throughout the country. Ph.D.'s produced in engineering must be sufficient to satisfy the needs for staffing the colleges of engineering plus the needs of industry in research and development. It is estimated that these needs are of the order of magnitude of 1,500 to 2,000 a year, or two to three times the number now being produced.

Second, why support research in the engineering sciences? One of the major tools for educating graduate students at the Ph.D. level is the research program on which the student engages and which results in his dissertation. Few people outside the engineering schools recognize the fact that the whole field of research that has been called "classical physics" is encompassed within the field of the engineering sciences. If basic research is to be done in the general fields of heat and radiation (both in the field of electromagnetic waves and sound), electricity, fluid mechanics, and the mechanics of solids, it must be done by the engineering schools of the country. The Departments of Physics have all that they can do to conduct research in the so-called areas of the "new" physics.

If the United States is to have a balanced research program, then adequate support must be given to graduate research in engineering and research in the basic fields of the engineering sciences.

RALPH A. MORGEN
Vice President, ECAC

ANALYSIS OF EDUCATIONAL POTENTIAL IN ENGINEERING COLLEGES

S. C. HOLLISTER

Dean, College of Engineering
Cornell University, Ithaca, New York

It is time that careful appraisal be made of what can be expected from the engineering colleges. In the past this has been done largely in terms of numbers of students. It should be clear that in the foreseeable future, however, this country will not be able to match the output of Russian engineering schools in terms of numbers. It is, in fact, not necessary that we do so if we can develop high enough *quality* in our output of engineering graduates.

This study was undertaken to provide an overall picture of the performance of engineering schools at various academic levels. For this purpose, the figures published by the U. S. Office of Education covering degrees granted in higher educational institutions of the country for 1954–1955 have been used. This is the last year for which figures are available.

The first step in the study was to separate, in both privately and publicly supported categories, those schools which gave only bachelor's degrees, those which gave only bachelor's and master's degrees, and those which gave degrees ranging from the baccalaureate to the doctorate. The latter group was then further subdivided to show which schools were giving at least 25 master's and 5 doctor's degrees in any one of the last three years of record.

Since it is generally recognized that an engineering school cannot be strong without also having strong support in mathematics, physics, and chemistry, it was thought desirable to include for each institution the number of master's and doctor's degrees awarded in each of these three fields, as well as those awarded in engineering. Institutions are arranged alphabetically by the states in which they are located.

In Group I there are 37 schools, 20 of which are privately supported and the remaining 17, tax-supported. Each of these schools has awarded at least 25 master's and 5 doctor's degrees in engineering in at least one of the three academic years, 1952–3, 1953–4, or 1954–5, these being the last three years of record. It is interesting to note that these 37 schools awarded in engineering 43% of the bachelor's degrees, 71% of the master's degrees, and 93% of the doctor's degrees.

The tabulation for Group I includes also the number of master's and doctor's degrees awarded in mathematics, physics, and chemistry. It is interesting that these same schools awarded nearly half the master's degrees and at least two-thirds of the doctor's degrees in these three fields of science. This is impressive testimony that there is real strength in the combination of these sciences with engineering.

The study of the table for Group I discloses that these 37 schools are carrying the major load at the highest levels in engineering education. Some of them show areas of weakness, especially at the doctoral level. None of them, however, can be allowed to remain weak, either in the interest of national defense or of the general economy.

Group II includes schools which granted fewer than 25 master's and

TABLE I

SUMMARY BY GROUPS

	First Degrees	Second Degrees				Doctorates			
	Eng.	Eng.	Math.	Phys.	Chem.	Eng.	Math.	Phys.	Chem.
Group I. (37)									
A. (20)	4256	1860	158	213	245	312	80	220	286
B. (17)	5375	1310	176	204	248	246	93	150	387
Total, Group I.	9631	3170	334	417	493	558	173	370	673
% of U.S.	(43)	(71)	(44)	(57)	(42)	(93)	(69)	(72)	(67)
Group II. (7)									
B. (7)	1117	121	27	18	27	18	7	20	26
% of U.S.	(5)	(3)	(4)	(2)	(2)	(3)	(3)	(4)	(3)
Group IIa. (17)									
A. (6)	528	205	21	17	17	4	11	32	34
B. (11)	1619	206	36	34	61	19	13	15	56
Total, Group IIa.	2147	411	57	51	78	23	24	47	90
% of U.S.	(10)	(9)	(8)	(7)	(7)	(4)	(10)	(9)	(9)
Group III. (57)									
A. (18)	2092	276	35	53	53	—	7	27	32
B. (39)	3482	506	72	64	151	—	17	18	71
Total, Group III.	5574	782	107	117	204	—	24	45	103
% of U.S.	(25)	(17)	(14)	(16)	(17)	—	(10)	(9)	(10)
Group IV. (98)									
A. (56)	2507	—	17	24	40	—	5	10	15
B. (42)	1613	—	18	6	49	—	—	—	1
Total, Group IV.	4120	—	35	30	89	—	5	10	16
% of U.S.	(18)	—	(5)	(4)	(8)	—	(2)	(2)	(2)
Totals Groups I–IV. (216)	22589	4484	560	633	891	599	233	494	908
% of U.S.	(100)	(100)	(74)	(87)	(76)	(100)	(93)	(97)	(90)
Totals for U.S.	22589	4484	761	729	1173	—	250	511	1005

TABLE II

SUMMARY BY YEARS

Year	First Degrees	Second Degrees				Doctorates			
	Eng.	Eng.	Math.	Phys.	Chem.	Eng.	Math.	Phys.	Chem.
1947–8	31096	4198	711	706	1360	257	128	198	569
1948–9	43604	4647	793	841	1427	360	126	266	749
1949–50	52248	4496	974	922	1576	417	160	358	953
1950–1	41473	4825	1109	973	1462	520	184	443	1046
1951–2	30549	4081	802	882	1409	529	206	485	1031
1952–3	24189	4066	677	721	1211	518	241	478	999
1953–4	22339	4204	706	714	1098	594	227	485	1013
1954–5	22589	4484	761	729	1173	599	250	511	1005

5 doctor's degrees in engineering not only in the last three years of record, but granted doctorates in all of those years. Group IIa lists schools which granted doctor's degrees in one or more, but not all, of the three years. Some show doctor's degrees granted in 1954–5 (the year tabulated) and

TABLE III

GROUP I. DEGREES GRANTED 1954–55

Institutions which granted 25 Master's and 5 Doctor's Degrees, or more, in Engineering, in any one of the years 1952–3, 1953–4, and 1954–5.

	First Degrees	Second Degrees				Doctorates			
	Eng.	Eng.	Math.	Phys.	Chem.	Eng.	Math.	Phys.	Chem.
A. *Privately Supported* (*20*)									
Cal. Inst. Tech.	61	99	—	5	1	21	3	22	16
Stanford	144	133	8	8	6	22	9	12	12
Yale	172	37	4	16	17	16	4	17	15
Ill. Inst. Tech.	277	62	—	10	3	16	2	6	12
Northwestern	115	36	5	5	4	9	2	5	18
Johns Hopkins	156	26	2	—	8	16	2	5	7
Harvard	25	72	16	37	27	20	10	19	20
Mass. Inst. Tech.	557	510	8	11	7	70	10	43	32
Wash. Univ. (St. L.)	103	17	—	5	5	7	1	9	6
Princeton	133	50	7	6	10	5	15	12	18
Columbia	110	156	24	19	28	19	2	15	21
*Cornell (5-year curric.)	236*	31	1	8	8	17	—	11	17
New York Univ.	362	188	34	22	22	7	8	11	16
Brooklyn, Poly. Inst. of	418	136	1	—	23	17	—	1	25
Rensselaer Poly. Inst.	444	56	3	6	5	8	—	2	3
Case Inst. Tech.	180	62	1	11	7	6	—	2	3
Carnegie Inst. Tech.	245	45	3	18	17	16	5	10	14
Lehigh	248	34	3	8	11	8	—	3	7
Penna., U. of	50	51	3	11	20	7	2	10	12
Pittsburgh, U. of	220	49	15	7	6	5	3	5	12
Totals	4256	1860	158	213	245	312	80	220	286
B. *Tax Supported* (*17*)									
California, U. of	490	145	21	47	18	26	27	42	48
Delaware, U. of	63	28	6	2	22	3	—	—	14
Georgia Inst. Tech.	442	74	1	2	2	3	—	—	2
Illinois, U. of	530	168	38	41	28	38	11	18	52
Purdue	760	154	12	9	37	29	9	12	36
Iowa St. College	263	35	10	7	16	14	10	6	24
Iowa, U. of	51	24	10	7	10	3	2	4	12
Mich. State Univ.	221	30	4	3	10	6	3	4	23
Michigan, U. of	310	215	52	22	22	35	12	14	20
*Minnesota, U. of (5-year)	307*	65	8	—	11	14	4	5	18
North Carolina St. Coll.	220	43	5	—	—	5	2	—	—
*Ohio State Univ. (5-year)	192*	64	3	22	18	14	1	15	35
Penna. St. Univ.	414	55	4	6	12	18	1	4	25
Texas A. & M. Coll.	366	44	—	8	4	1	—	—	4
Texas, U. of	225	47	3	9	17	15	3	11	18
Washington, U. of	271	49	6	6	7	5	4	2	16
Wisconsin, U. of	250	80	13	13	14	17	9	13	40
Totals	5375	1310	176	204	248	246	93	150	387

* 5-year curricula.

TABLE IV

Group II. Degrees Granted 1954–55

Institutions which granted fewer than 25 Master's and 5 Doctor's Degrees in Engineering in any one of the years 1952–3, 1953–4, 1954–5, but which granted both in those years.

	First Degrees	Second Degrees				Doctorates			
	Eng.	Eng.	Math.	Phys.	Chem.	Eng.	Math.	Phys.	Chem.
A. *Privately Supported* (*0*)									
None									
B. *Tax Supported* (7)									
Colo. Schl. Mines	132	11	—	—	—	2	—	—	—
Maryland, U. of	97	22	4	5	6	2	2	8	9
Missouri, U. of	298	22	4	6	1	4	1	5	5
Cincinnati, U. of	191	3	2	1	4	2	2	1	2
Tennessee, U. of	124	21	6	—	10	2	1	6	4
Va. Poly. Inst.	182	36	7	4	1	4	1	—	1
W. Va., U. of	93	6	4	2	5	2	—	—	5
Totals	1117	121	27	18	27	18	7	20	26

Group IIa. Degrees Granted 1954–55

Institutions which granted fewer than 25 Master's and 5 Doctor's Degrees in 1952–3, 1953–4, and 1954–5, but did not grant Doctor's Degrees in all three of these years.

	First Degrees	Second Degrees				Doctorates			
	Eng.	Eng.	Math.	Phys.	Chem.	Eng.	Math.	Phys.	Chem.
A. *Privately Supported* (*6*)									
Notre Dame	180	16	8	2	6	—	1	4	15
Stevens Inst. Tech.	128	144	—	—	—	1	—	—	—
Syracuse	89	28	—	—	—	2	3	1	3
Brown	27	2	7	4	—	—	6	11	5
*Rice Inst.	51*	9	—	6	1	1	—	8	2
Catholic U. of Am.	53	6	6	5	10	—	1	8	9
Totals	528	205	21	17	17	4	11	32	34
B. *Tax Supported* (*11*)									
Colo. A. & M.	63	9	—	1	2	1	—	—	—
Colo., U. of	222	31	1	4	8	1	1	4	4
Florida, U. of	184	16	8	3	5	4	2	1	10
Kansas, U. of	134	8	4	6	2	—	3	2	7
Kentucky, U. of	139	16	—	1	9	—	2	—	2
La. State U.	197	32	3	5	—	2	—	1	—
Okla. A. & M.	173	26	5	1	8	2	1	—	4
Okla., U. of	236	35	4	1	9	—	1	1	4
Ore. St. Coll.	125	11	6	10	13	2	2	3	15
Utah St. Ag. Coll.	43	6	—	—	2	—	—	—	—
Utah, U. of	103	16	5	2	3	7	1	3	10
Totals	1619	206	36	34	61	19	13	15	56

* 5-year curricula.

TABLE V

GROUP III. DEGREES GRANTED 1954–55

Institutions which granted Master's but no Doctor's Degrees in Engineering in 1954–5.

	First Degrees	Second Degrees				Doctorates			
	Eng.	Eng.	Math.	Phys.	Chem.	Eng.	Math.	Phys.	Chem.
A. *Privately Supported (19)*									
Rose Poly.	54	2	—	—	—	—	—	—	—
Tulane	44	4	3	2	5	—	3	—	7
Northeastern	279	46	—	—	6	—	—	—	—
Worcester Poly.	124	6	—	—	—	—	—	—	—
Detroit, U. of	171	1	4	2	8	—	—	—	—
St. Louis U.	106	8	6	2	4	—	2	4	4
Clarkson Coll. Tech.	123	7	—	—	—	—	—	—	—
Union Coll.	36	2	—	—	—	—	—	—	—
†Buffalo, U. of (not accred.)	67	8	1	1	5	—	—	4	1
Rochester, U. of	36	4	—	12	1	—	—	12	9
Webb (Nav. Arch.)	16	4	—	—	—	—	—	—	—
Tulsa, U. of	77	17	1	—	—	—	—	—	—
Bucknell	34	1	1	3	2	—	—	—	—
Drexel Inst. Tech.	468	44	—	5	9	—	—	—	—
Villanova	72	1	2	—	—	—	—	—	—
Vanderbilt	90	1	6	15	6	—	1	3	4
So. Calif., U. of	204	110	11	6	2	—	1	3	7
So. Methodist	41	9	—	2	3	—	—	—	—
Geo. Wash. U.	50	1	—	3	2	—	—	1	—
Totals	2092	276	35	53	53	—	7	27	32
B. *Tax Supported (38)*									
Ala. Poly. Inst.	232	6	4	1	4	—	—	—	—
Ala., U. of	82	5	1	—	6	—	—	1	—
Ariz., U. of	122	3	1	1	6	—	—	—	1
Ark., U. of	79	13	2	2	6	—	—	—	4
Conn., U. of	89	14	2	5	7	—	—	2	5
†Ga., U. of (not accred.)	11	2	3	2	3	—	2	—	—
Ida., U. of	83	11	—	—	—	—	—	—	—
Kans. St. Coll.	128	11	5	5	13	—	—	—	5
*Louisville, U. of (5-year)	*60	7	—	1	2	—	—	—	4
Maine, U. of	109	12	2	2	5	—	—	—	—
Lowell Inst.	38	4	—	—	8	—	—	—	—
Mass., U. of	75	4	4	—	8	—	—	—	4
Mich. Mines	177	21	—	—	2	—	—	—	—
Wayne	98	38	6	4	8	—	—	—	12
Miss. St. Coll.	98	1	—	1	—	—	—	—	—
Mont. Mines	26	5	—	—	—	—	—	—	—
Mont. St. Coll.	83	6	3	—	5	—	—	—	—
Nebr., U. of	104	6	2	1	10	—	—	1	5
N.H., U. of	51	2	5	2	16	—	—	—	—
Newark Coll. Engrg.	260	115	—	—	—	—	—	—	—
Rutgers	73	21	16	4	8	—	1	2	9
N. Mex. A. & M.	38	1	—	1	—	—	—	—	—
N. Mex., U. of	79	10	2	1	3	—	—	2	—
Alfred U. (NYSS Ceramics)	30	1	—	2	—	—	—	—	—
Coll. City of N.Y.	328	43	2	—	—	—	—	—	—
†N. Car., U. of (not accred.)	—	5	3	3	5	—	13	4	12
N. Dak., U. of	51	1	2	3	3	—	—	—	—

† Not accredited by ECPD.
* 5-year curricula.

TABLE V—(*Continued*)

	First Degrees	Second Degrees				Doctorates			
	Eng.	Eng.	Math.	Phys.	Chem.	Eng.	Math.	Phys.	Chem.
Toledo, U. of	58	9	1	—	4	—	—	—	—
R. I., U. of	68	4	—	4	3	—	—	—	—
Clemson	143	4	—	3	2	—	—	—	—
S. Dak. Mines	52	1	—	—	—	—	—	—	—
S. Dak. St. Coll.	37	3	—	—	—	—	—	—	—
Tex. Coll. A. & I.	31	1	—	3	1	—	—	—	—
†Houston, U. of (not accred.)	134	25	1	2	1	—	—	—	—
Va., U. of	53	12	3	9	7	—	1	5	7
Wash., St. Coll. of	86	5	1	1	5	—	—	1	3
Wyo., U. of	83	3	1	1	—	—	—	—	—
U.S N. Ac. & P.G. Schl.	133	71	—	—	—	—	—	—	—
Totals	3482	506	72	64	151	—	17	18	71

† Not accredited by ECPD.

TABLE VI

GROUP IV. DEGREES GRANTED 1954–55

Institutions which granted only First Degrees in Engineering in 1954–5.

	First Degrees	Second Degrees			Doctorates		
	Eng.	Math.	Phys.	Chem.	Math.	Phys.	Chem.
A. *Privately Supported* (57)							
Tuskegee Inst.	4	—	—	3	—	—	—
John Brown U.	7	—	—	—	—	—	—
Coll. of Pac.	1	—	—	2	—	—	—
Loyola U. of L.A.	26	—	—	—	—	—	—
Colo. Coll.	5	—	—	1	—	—	—
#Denver, U. of	44	3	1	1	—	—	—
Hillyer Coll.	10	—	—	—	—	—	—
Trinity Coll.	7	—	—	1	—	—	—
Bridgeport, U. of	25	—	—	—	—	—	—
Miami, U. of	89	4	2	5	—	—	—
#Bradley U.	60	—	1	3	—	—	—
Chi. Tech. Coll.	113	—	—	—	—	—	—
Fournier Inst. Tech. (closed 1955)	15	—	—	—	—	—	—
Millikin U.	12	—	—	—	—	—	—
N. Cent. Coll.	4	—	—	—	—	—	—
Evansville Coll.	21	—	—	—	—	—	—
Ind. Tech. Coll.	181	—	—	—	—	—	—
Tri State Coll.	227	—	—	—	—	—	—
Valparaiso U.	47	—	—	—	—	—	—
Boston U.	7	3	3	3	3	2	5
Merrimack Coll.	4	—	—	—	—	—	—
#Tufts	94	—	4	7	—	—	—
Detroit Inst. Tech.	43	—	—	—	—	—	—
General Motors Inst.	162	—	—	—	—	—	—
Lawrence Inst. Tech.	107	—	—	—	—	—	—
#Dartmouth	26	—	2	2	—	—	—
Fairleigh Dickinson	23	—	—	—	—	—	—
#Cooper Union	109	—	—	—	—	—	—
#Manhattan Coll.	137	—	—	—	—	—	—

Accredited by ECPD in one or more curricula.

TABLE VI—(*Continued*)

	First Degrees	Second Degrees			Doctorates		
	Eng.	Math.	Phys.	Chem.	Math.	Phys.	Chem.
#Pratt Inst.	29	—	—	—	—	—	—
#Duke Univ.	68	2	4	6	2	8	10
Antioch Coll.	15	—	—	—	—	—	—
#Fenn Coll.	87	—	—	—	—	—	—
#Ohio Northern	15	—	—	—	—	—	—
#Dayton, U. of	40	—	—	—	—	—	—
#Youngstown, Coll.	23	—	—	—	—	—	—
Portland, U. of	16	—	—	—	—	—	—
Geneva Coll.	19	—	—	—	—	—	—
Grove City Coll.	16	—	—	—	—	—	—
#Lafayette Coll.	85	—	—	—	—	—	—
Pa. Mil. Coll.	27	—	—	—	—	—	—
Phila. Textile Inst.	43	—	—	—	—	—	—
#Swarthmore	20	—	—	—	—	—	—
R.I. Schl. Design	17	—	—	—	—	—	—
Chattanooga, U. of	11	—	—	1	—	—	—
Brigham Young U.	6	—	4	1	—	—	—
#Norwich U.	43	—	—	—	—	—	—
Hampton Inst.	4	—	—	—	—	—	—
Gonzaga U.	29	—	—	—	—	—	—
#Santa Clara, U. of	44	—	—	—	—	—	—
St. Martins Coll.	2	—	—	—	—	—	—
Seattle U.	29	—	—	—	—	—	—
Walla Walla Coll.	6	—	—	—	—	—	—
Davis & Elkins Coll.	21	—	—	—	—	—	—
#Marquette U.	123	5	3	1	—	—	—
Milwaukee Sch. Engrg.	40	—	—	—	—	—	—
#Howard U.	19	—	—	3	—	—	—
Totals	2507	17	24	40	5	10	15
B. *Tax Supported (41)*							
Cal. Maritime Ac.	16	—	—	—	—	—	—
Cal. St. Poly.	133	2	—	—	—	—	—
Fresno St. Coll.	16	—	—	—	—	—	—
L.A. St. Coll. Ap. A. & S.	8	—	—	—	—	—	—
San Diego St. Coll.	21	—	—	—	—	—	—
San Jose St. Coll.	29	5	—	—	—	—	—
#Wichita, U. of	25	2	—	—	—	—	—
#La. Poly. Inst.	68	—	—	—	—	—	—
S.W. La. Inst.	32	—	—	—	—	—	—
Maine Maritime Ac.	35	—	—	—	—	—	—
Bradford Durfee Tech.	13	—	—	—	—	—	—
Mass. Maritime Ac.	30	—	—	—	—	—	—
New Bedford Inst. Text.	19	—	—	—	—	—	—
#Miss., U. of	35	2	—	2	—	—	—
Omaha, U. of	18	—	—	—	—	—	—
#Nevada, U. of	32	1	—	2	—	—	—
N. Mex. Inst. M. & T.	17	—	1	—	—	—	—
Maritime Coll. N.Y.	55	—	—	—	—	—	—
N. Car. Ag. & Tech. Coll.	15	—	—	—	—	—	—
#N. Dak. Ag. Coll.	77	—	—	12	—	—	—

Accredited by ECPD in one or more curricula.

TABLE VI—(*Continued*)

	First Degrees	Second Degrees			Doctorates		
	Eng.	Math.	Phys.	Chem.	Math.	Phys.	Chem.
#Ohio U. (Athens)	66	1	—	6	—	—	—
#Akron, U. of	25	—	1	9	—	—	—
#Citadel	58	—	—	—	—	—	—
S.C. St. Coll.	5	1	—	2	—	—	—
#S.C., U. of	66	1	—	1	—	—	1
Tenn. A. & I. U.	6	—	—	2	—	—	—
Tenn. Poly. Inst.	36	—	—	—	—	—	—
Lamar St. Coll.	38	—	—	—	—	—	—
Prairie View A. & M.	2	—	—	—	—	—	—
#Texas Tech. Coll.	131	3	2	1	—	—	—
#Texas Western	25	—	—	—	—	—	—
#Vt., U. of	35	—	1	4	—	—	—
#Va. Mil. Inst.	109	—	—	—	—	—	—
Marshall Coll.	9	—	—	6	—	—	—
W. Va. Inst. Tech.	5	—	—	—	—	—	—
Wis. Inst. Tech.	17	—	—	—	—	—	—
#U.S.C.G. Acad.	76	—	—	—	—	—	—
U.S. Merch. Mar. Acad.	65	—	—	—	—	—	—
#Alaska, U. of	7	—	—	—	—	—	—
Puerto Rico, U. of	96	—	—	—	—	—	—
#Hawaii, U. of	42	—	1	2	—	—	—
Totals	1613	18	6	49	—	—	1

Accredited by ECPD in one or more curricula.

some do not. Group II has much the same characteristics as Group I, except that the numbers of degrees awarded at the higher levels fall somewhat below those in Group I. The interdependence of engineering and the physical sciences is again clear.

Groups I, II, and IIa taken together constitute all of the schools that granted doctor's degrees in engineering in 1952–3, 1953–4, and 1954–5, and represent 28% of the engineering schools listed (see Table I). These groups together granted 58% of the bachelor's, 83% of the master's, and all of the doctor's degrees awarded in 1954–5. This means that 72% of the engineering schools of the United States granted only 42% of the bachelor's, 17% of the master's, and no doctor's degrees in that year. These three groups also granted more than half of the master's and more than three-quarters of the doctor's degrees awarded in mathematics, physics, and chemistry.

Group III lists the schools that awarded no doctor's degrees in 1952–3, 1953–4, or 1954–5. These 57 schools awarded about a seventh of the master's and 10% of the doctor's degrees in mathematics, physics, and chemistry.

Group IV lists 98 schools that awarded no graduate degrees in engineering in 1954–5. They awarded only 4% to 8% of the master's and only 2% of the doctor's degrees in mathematics, physics, and chemistry.

Of the 216 schools listed, all those in Groups I, II and IIa are accredited by ECPD; 35 of the 39 schools of Group III and 34 of the 98 schools of Group IV are so accredited in one or more curricula. Thus 68 schools listed

(Continued on page 607)

IMPRESSIONS OF A VISIT TO SOME UNIVERSITIES IN WESTERN EUROPE

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During the summer of 1957 the writer visited universities, government research establishments and private institutions in Western Europe. His purpose was to exchange information, study recent developments in teaching, research and engineering practice, and to renew former contacts. The trip,through various parts of England, Holland, Western Germany and Switzerland, was undertaken mainly to study applied science and engineering in these countries. A brief history of universities may give perspective to the impressions gained.

The origin of European universities goes back about 1000 years to the medical and law schools founded in the 10th and 11th centuries in Italy and to the philosophy and theology schools founded in the 12th century in France and England. The organization of the early medieval universities was very similar to that of the present day. At the head was a rector with a board of governors and a senate. To the four main faculties mentioned above were added science and engineering, during the 17th and 19th centuries, respectively. The professors lived from honorariums paid by their students. The original purpose of awarding degrees of either master or doctor was to give graduate students the right and duty to teach in their faculty at a university.

During the latter part of the Middle Ages the universities became financially more dependent on the towns and provinces, and at the same time, lost some of their freedom and became more utilitarian. At the beginning of the last century university life was reorganized and was guided by the principles that the ideal university represents the unity of all knowledge, the combination of teaching and research, intellectual freedom and the search for the truth.

In order that universities could carry out both teaching and research in perfect freedom, a compromise was made between the early internal organisation and later financial support by the State, which has continued to the present day. Thus, the European universities are now independent organisations in all academic matters of teaching and research, while the State provides most of the physical facilities and the greater part of the budget. Both the private universities as well as the publicly controlled institutions receive 70 to 75 per cent of their income from public funds and only about 30 per cent in roughly equal proportions from fees, endowments and miscellaneous revenues.

The great dependence on government grants may give rise to concern of political interference with the work of the universities, but little of that has actually occurred. University authorities mentioned that there is no alternative financial source of such magnitude and some risk must, therefore, be accepted. In addition, the independence of universities depends on the reputation of their work rather than on official guarantees.

The students' fees, which represent only 10 per cent of the university income, are very low and enable students to spend summers on travels or private studies without the need of summer employment. Further, numerous scholarships are available and are held by about three quarters of all students. These are partly State scholarships and partly awarded by industry, which has founded many chairs and made gifts for buildings, residences and annual contributions towards the cost of teaching and research.

Academic staff have a high standing in the eyes of the European public and students, similar to the best of the professions. The professor is deeply respected and occupies an honoured position. At the continental European universities practically every subject has a separate chair occupied by a full professor who has two to three assistants; the professor is expected to have a doctor's degree and he gives most of the lectures, so that students profit by the high quality of teaching.

In order to attract and retain the best professors, good salaries are paid, fully comparable to those of industry. The average teaching load in Western Europe is six hours per week (varying from two to about eight hours per week), which gives professors plenty of time for research and consulting, each activity accounting for approximately one third of his time. Assistants are generally junior staff who are doing postgraduate work under their professor; they supervise the problems, drawing office and laboratory instruction. Their instructional load is similar to that of a professor and their pay is competitive with that of industry. The staff-to-student ratio varies from about one in five to one in ten, which is relatively high, and explains the heavy cost of educating students in Europe.

Admission of undergraduate students is by final high school examination, or an equivalent university entrance examination at an age of 17 to 18, the standard being at least that of senior matriculation. On the average, about one-quarter of the applicants are accepted by the universities for study. In some of the older British universities the percentage of successful applicants is as low as five per cent, while at some of the Continental universities, up to one-half of the applicants are accepted. Those rejected have to go to institutions with lower standards, but one-quarter to one-half of those who wish to study cannot do so anywhere. In fact, only about two per cent of the age group 18 to 22 receive a university education at present, which is a very low percentage. In the past students went to several universities during their course of study, but recently this trend has decreased and most of them now stay the full time of four years at one university.

The main method of imparting knowledge at the undergraduate level is by lectures. Even in engineering the time spent on problems, drawings and laboratory work is only about one half of that which lectures take up on the Continent, while in England, an approximately equal amount of time is spent on lectures and practical work. The studies are, thus, rather theoretical and emphasis is placed on the fundamentals of the subject.

Students are left to themselves to a considerable extent and they regard university courses as difficult, in spite of their long high school education. The failure rate is high, both at the preliminary examinations and at the final degree examination. Notwithstanding the small admission quotas and careful selection of students, from

one quarter to three quarters of all students fail to obtain degrees.

The slowly increasing enrollment has made programs of expansion necessary, and an approximate 25 per cent increase is provided for during the next ten years, apart from modernization of existing facilities. The buildings are generally five to ten stories high, of modern frame construction; they are frequently air conditioned and well equipped with libraries, the latest apparatus and large lecture theatres (the largest one visited holds 1000 students and had all the audio and visual aids of a modern theatre).

The lowest floors in these buildings accommodate lecture halls, undergraduate and research laboratories and drawing offices. Intermediate floors contain libraries, staff and students' common rooms, as well as dining rooms where most staff and students take their midday meals at very reasonable cost. Upper floors have staff offices and postgraduate rooms. In spite of the height of the buildings, students use mainly the lower three to four floors, while staff and research workers occupy the upper and quieter space.

Residences are considered to be an essential part of a British university; they are frequently provided to accommodate about one-quarter of the students, but not more than one-half can reside even in the older universities. Nevertheless, it is intended that all students should spend at least one year in a residence together with some of the staff, so that the social collegiate benefits of communal student life and extracurricular activities are readily available to them.

As mentioned earlier, the function of the universities is as much the advancement of knowledge by research as the dissemination of knowledge by teaching. Great emphasis is, therefore, placed on all staff to conduct original research throughout the whole of the academic year. It is believed that teaching up to first degree standard cannot be of high quality unless the staff are in contact with and able to conduct postgraduate research in their chosen field of study. The voluminous books and papers published by many professors could not have been written without much full-time research, since holidays are generally taken up by travels and conferences, and sabbatical leave exists more on paper than in reality.

In order to integrate teaching and research, special graduate departments do not usually exist. Postgraduate studies are carried out without formal courses by means of seminars and analytical or experimental work in research laboratories of the university. In this way the postgraduate students work together with their professors to solve research problems and thus learn the scientific method of approach right from the start.

The general impression of the visits was that both staff and students work with enthusiasm and in a stimulating atmosphere. The students appreciate the fortunate position of being allowed to study and to enjoy the privileges which university life offers them.

ENGINEERING TEACHING AND RESEARCH SALARIES VERSUS INDUSTRIAL RESEARCH SALARIES

F. L. FOSTER AND T. W. HARRINGTON, JR.

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Massachusetts Institute of Technology, Cambridge 39

Presented at the ECRC Conference for Presidents, Institutional Representatives, Deans, Directors of Research, 65th Annual Meeting, Cornell University, June, 1957.

Surveys of salaries being paid to engineers and scientists in the fields of teaching and research are the order of the day. Unfortunately, it appears that the results of one survey are seldom compatible with those of another, and indeed almost defy comparison.

In an effort to improve and strengthen its position in compensating its research personnel, the Massachusetts Institute of Technology, through its Division of Sponsored Research, conducted during the fall of 1956 a selective survey of salaries being paid to professional research and development engineers and scientists. This survey was not undertaken with the thought of supplanting or competing with other surveys, but it was designed primarily to be useful and meaningful to M.I.T. and the other participants in the survey.

Its scope covered 21 industrial and educational organizations performing research and development, with salaries current as of September to December, 1956. Participants in the survey were selected from the aircraft, automobile, chemical, electronic, petroleum, pharmaceutical, and research and development industries in all sections of the country. It is felt that the organizations selected present an excellent sample of the professional research and development personnel employed in the United States.

College Research Staffs

With the M.I.T. Survey available, the next step in approaching the subject of this paper was to gather data concerned with the salaries being paid to *full-time professional research personnel* employed at the universities. Such information not being available, requests were sent to the Presidents of 63 Land Grant Colleges and State Universities and 18 additional educational institutions carrying on extensive engineering programs.

This mailing list was prepared by Dr. H. W. Barlow, Director of the Washington State Institute of Technology at Pullman, Washington. It was requested that data be supplied in the same form as that used for the M.I.T. Survey. Responses were received from 77 of the 81 universities, of which 45 supplied useful information. The numbers of full-time professional research personnel employed at these institutions are noted below:

No. of schools reporting	No. of full-time professional research personnel
8	100 or more
10	50 to 100
11	10 to 50
16	Fewer than 10

Of the 32 supplying no data, most indicated that no professional personnel were employed on research full time; a few could not supply the data in the form requested; others could

not comply because of lack of time. Many in this group indicated that most of their faculty members spent varying amounts of time on research. It is true that the time available was short, and the remarkable return is indicative of the degree of interest and whole-hearted cooperation displayed by the officials of the participating universities.

Faculties

The third area for consideration concerns the salaries paid to engineering faculties; and since several surveys have been conducted in this area during the past year, it seemed best that an attempt be made to use the data already available. Furthermore, it appeared inappropriate to ask the universitiy administrators to supply further information.

The National Education Association in a Research Bulletin dated October, 1956, provided a great deal of information on "Salaries Paid and Salary Practices in Universities, Colleges, and Junior Colleges, 1955–56." Unfortunately, the data were not presented in a form adaptable for use in this paper. The Special Surveys Committee of Engineers Joint Council presented in January, 1957, Report Number 102 entitled "Professional Income of Engineers, 1956," from which permission was granted to use the data and curves setting forth "Basic Teaching Salaries of Engineers in Engineering Education." The Engineering Manpower Commission of Engineers Joint Council, during December, 1955, and the first quarter of 1956, also prepared a paper entitled "Supply—Demand and Salary Structure of Engineering Education Staffs," data from which are used herein with permission from the Engineers Joint Council.

M.I.T. Survey Basis

Because the M.I.T. Survey data form the basis for consideration of industrial research salaries, the approach used in conducting the survey should be explained. Each group participating was contacted personally so that a clear understanding existed between those supplying data and those using it as to the purpose of the study, the type of information desired, the manner in which the data were to be applied, and the end results expected. The 21 participating companies supplied a sample of 13,786 individual salaries. The data collected were treated in the manner commonly employed in dealing with maturity curves, age being plotted against monthly salary.

The arithmetic mean was selected as a measure of the central tendency of the data acquired for the following reasons:

1. It describes the distribution by selecting a score which can be assumed to be typical of that distribution.

2. Each score is taken into consideration, so that misrepresentation of central tendency in distributions which are positively skewed is avoided. The distribution of research salaries is so skewed because of the large numbers of younger personnel in the field. The use of median values, a common approach, yields an abnormally low curve which does not accurately picture the distribution as a whole and may effectively disregard as much as 50 per cent of the sample.

3. The mean falls near the center of distribution, midway between the two extremes of the range, whereas the median value in positively skewed distributions falls closer to the lower limit of the range.

4. The mean has high reliability from one distribution to another.

As a measure of dispersion, the root-mean-square deviation or standard deviation was employed. The

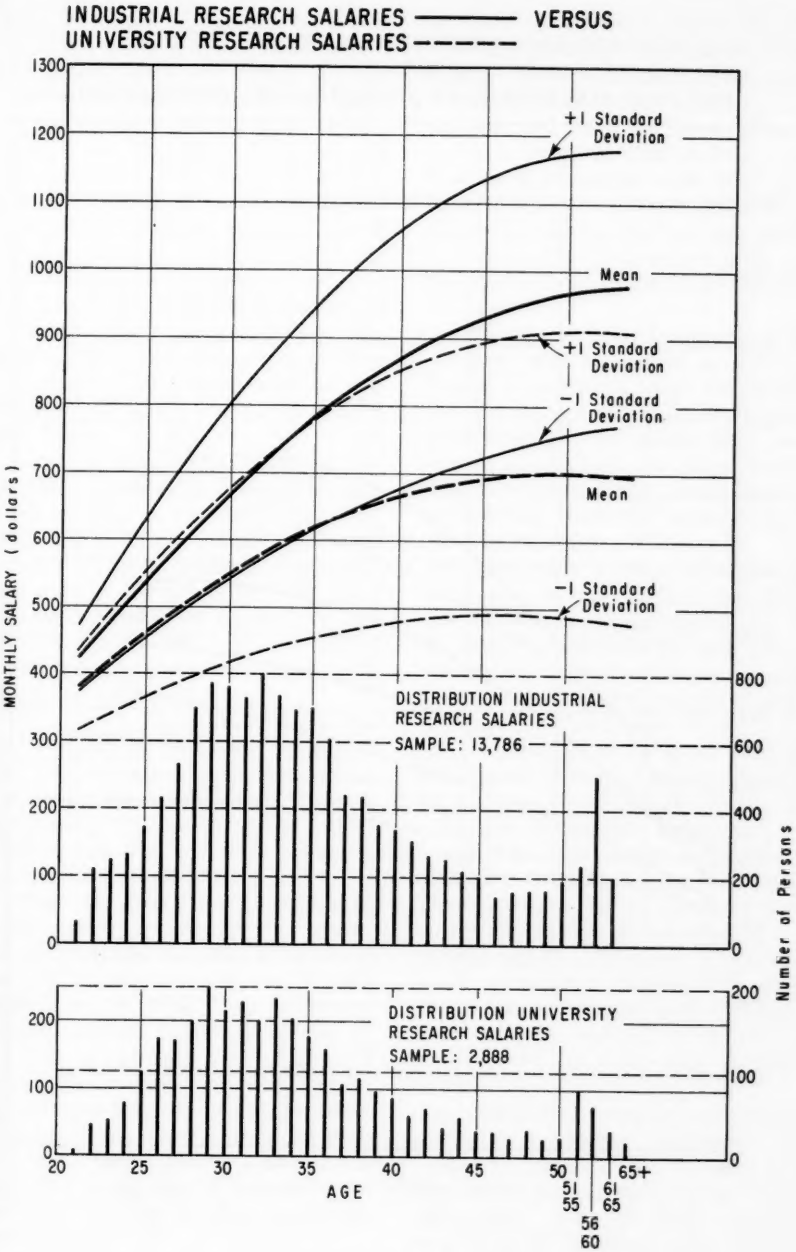
INDUSTRIAL RESEARCH SALARIES ——— VERSUS
UNIVERSITY RESEARCH SALARIES - - - - -
MONTHLY SALARY (dollars)
+1 Standard Deviation
Mean
+1 Standard Deviation
-1 Standard Deviation
Mean
-1 Standard Deviation
DISTRIBUTION INDUSTRIAL RESEARCH SALARIES
SAMPLE: 13,786
DISTRIBUTION UNIVERSITY RESEARCH SALARIES
SAMPLE: 2,888
Number of Persons
AGE
20
25
30
35
40
45
50
51 55
56 60
61 65
65+

FIG. 1.

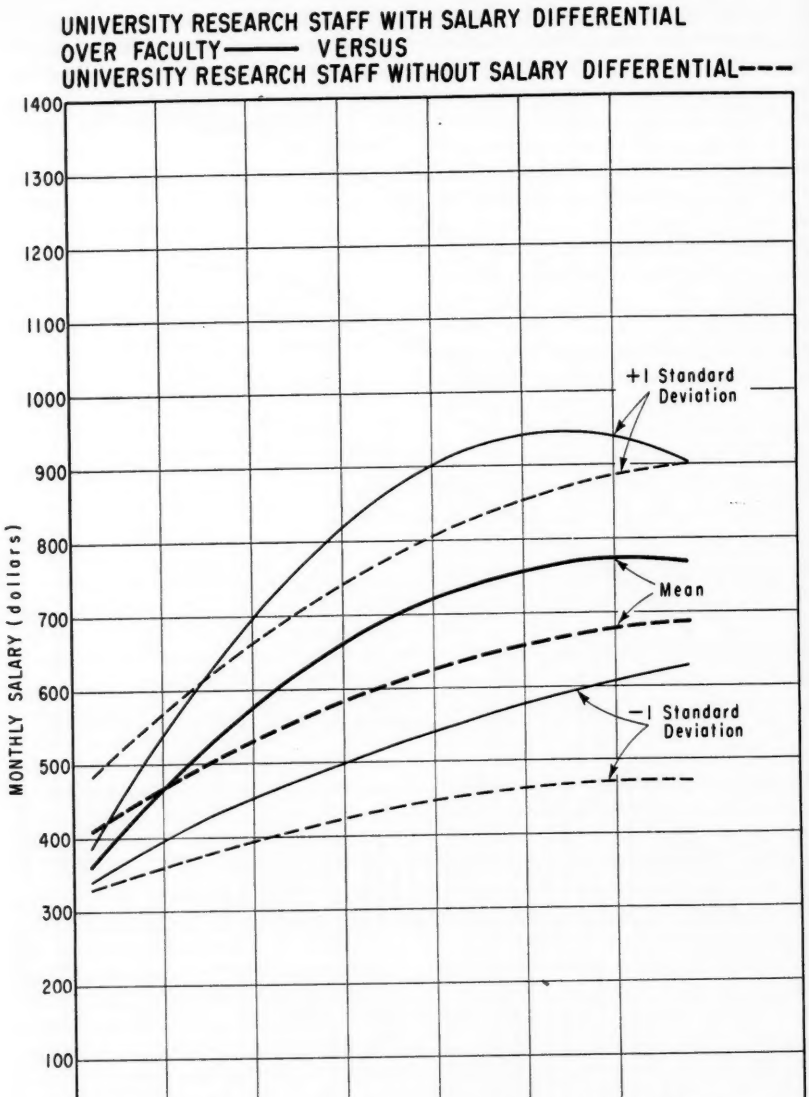
UNIVERSITY RESEARCH STAFF WITH SALARY DIFFERENTIAL
OVER FACULTY——— VERSUS
UNIVERSITY RESEARCH STAFF WITHOUT SALARY DIFFERENTIAL---
MONTHLY SALARY (dollars)
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
+1 Standard Deviation
Mean
−1 Standard Deviation
20
25
30
35
40
45
50
51 55
56 60
61 65
AGE

FIG. 2.

latter is simply an average deviation of scores which are dispersed about the arithmetic mean. It has the advantage of being symmetrical about the arithmetic mean, while quartiles are not always symmetrical about the median. The area contained within the limits of the plus-or-minus 1 standard deviation contains about 68% of the total sample. The standard deviation is less subject to sampling and grouping errors, and gives a measure of higher reliability. In plotting the results of the survey, the distribution of the number of salaries for each age group was pictured on a bar chart.

The data collected on university research salaries were handled in the same manner as for the M.I.T. Survey. Although the sample was much smaller, a quite uniform dispersion was evident out to age 40. The sample available totaled about 3200, although some of the data were not in useable form, and some arrived too late to be included.

For direct comparison with the M.I.T. Survey, the mean curve and the plus-or-minus 1 standard deviation were computed. Figure 1 shows graphically the results of the M.I.T. Survey and the university research salaries on a single chart.

There are several points to keep in mind when reviewing this chart. Monthly salaries are used in all cases, and the university survey can be considered on the same basis as the industrial in that nearly all of the 45 schools supplying data indicated clearly that the full-time research personnel were employed on a 12-month-per-year basis. Two schools did state that employment was for a shorter period, but since only 5 persons were involved, they do not affect the results significantly.

Each school reporting was asked to indicate whether or not a salary differential existed between the full-time research personnel and the teaching faculty. Ten of the 45 schools supplying data indicated that some scale differential did exist, and these schools had 1140 full-time research staff. The remaining 35 schools, with 2060 staff members, noted no scale differential. Figure 2 bears out the fact that there is a noticeable difference in scale for those schools which indicated a differential.

Although no information regarding vacations was requested, it was indicated in many cases that one month was generally in order, although there were cases of two weeks after one year of employment and three weeks after five to ten years, perhaps somewhat better than that generally offered by industry.

The question of fringe benefits was also raised; in most cases it appeared that full-time research staff received the same consideration for sick leave, retirement, hospitalization and health insurance as did the teaching staff. As to tenure plans, there seems to be no set approach, about 60 per cent of the schools treating research staff in the same way as teaching faculty.

Perhaps of primary importance in comparing salary scales is the handling of outside consulting privileges. There seems to be no clear-cut pattern. Twenty-five of the schools, reporting 925 people, allow consulting work; seventeen, employing 1995 staff, do not; three colleges, with 280 full-time research staff, have no policy stated or do not make their position clear.

It is perhaps of some interest to consider the consulting privileges accorded to research staff in those ten institutions having some salary scale differential. Four of these schools, employing 839 full-time research staff, do not allow consulting; five, employing 219, do; and one, employing 82

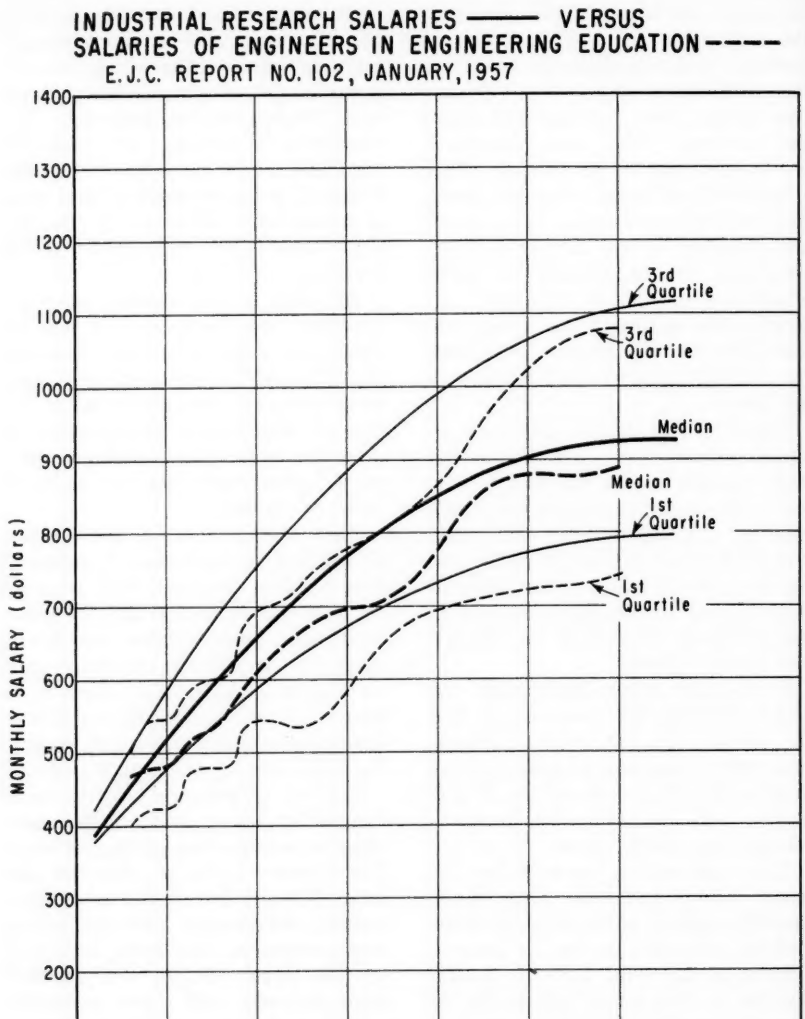
INDUSTRIAL RESEARCH SALARIES —— VERSUS
SALARIES OF ENGINEERS IN ENGINEERING EDUCATION----
E.J.C. REPORT NO. 102, JANUARY, 1957
MONTHLY SALARY (dollars)
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
3rd Quartile
3rd Quartile
Median
Median
1st Quartile
1st Quartile
20
25
30
35
40
45
50
65
AGE
51 61
55 65
56
60

FIG. 3.

persons, allows it in special cases. These figures fail to prove much, although it does appear that nearly 75 per cent of the research staff employed in universities paying such people at a higher rate than teaching faculty are not accorded consulting privileges.

The data immediately available and concerned with engineering teaching salaries are not in a form which allows comparison with the M.I.T. survey as originally prepared. The M.I.T. data had to be reworked to determine the median and upper and lower quartile curves and, as will become apparent, several assumptions had to be made to prepare charts which make possible comparative study.

The Engineers Joint Council Report Number 102 presents a curve for Basic Teaching Annual Salary of Engineers in Engineering Education by year of Entry in the Profession. The data for this were obtained through individual questionnaires received from educators, an approach which was employed in recognition that the majority of engineering educators supplement their salaries through earnings in other engineering activities.

Data regarding total earnings were also obtained in this survey but are not used in this paper. Some of the material from the EJC survey is heterogeneous because the salaries reported may be either on a calendar or academic year base. However, Figure 3 attempts to reproduce the EJC curves so that they can be compared with the M.I.T. survey of research salaries.

The Engineers Joint Council accumulated and presented further information on Engineering Faculty Salaries for the Academic Year 1955–56. An attempt is made here to correlate the results of this survey with the M.I.T. Survey data reduced to median and quartile curves. The EJC data used are set forth in Table I.

The approach made endeavors to outline the areas into which most of

TABLE I

SALARY STRUCTURE OF ENGINEERING FACULTY
ACADEMIC YEAR 1955–56—ACCREDITED ENGINEERING COLLEGES
MONTHLY AND ANNUAL RATES—9-MONTH CONTRACT

	Assistant Professor		Associate Professor		Professor	
	Monthly Rate	Basic Annual Rate	Monthly Rate	Basic Annual Rate	Monthly Rate	Basic Annual Rate
Lower Limit of Salary Bracket (Starting Salary)						
Lowest of Lower Limit	$367	$3,300	$ 444	$ 4,000	$ 533	$ 4,800
Highest of Lower Limit	667	6,000	778	7,000	1,111	10,000
Upper Limit of Salary Bracket						
Lowest of Upper Limit	478	4,300	567	5,100	667	6,000
Highest of Upper Limit	939	8,450	1,111	10,000	2,000	18,000
Bracket Containing Majority of Institutions						
Bracket	444 to 722	4,000 to 6,500	500 to 833	4,500 to 7,500	533 to 1,133	5,000 to 10,200
Percentage of Institutions in Bracket	86		82		71	

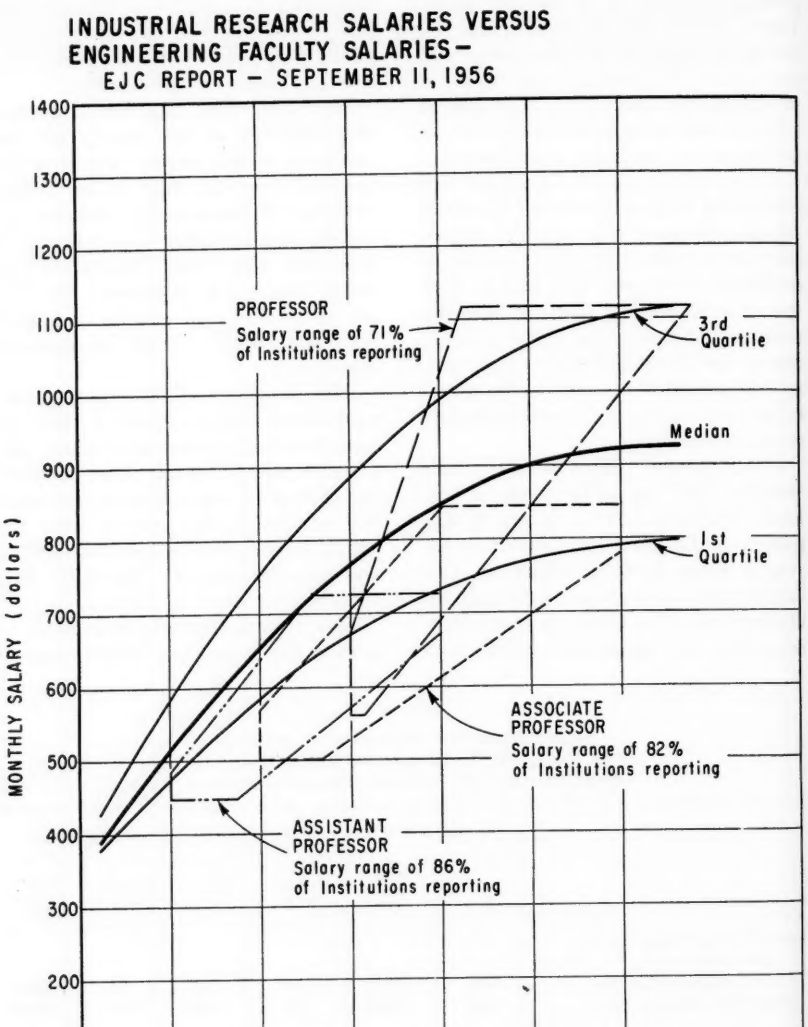
INDUSTRIAL RESEARCH SALARIES VERSUS
ENGINEERING FACULTY SALARIES—
EJC REPORT — SEPTEMBER 11, 1956
MONTHLY SALARY (dollars)
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
PROFESSOR
Salary range of 71%
of Institutions reporting
3rd
Quartile
Median
1st
Quartile
ASSOCIATE
PROFESSOR
Salary range of 82%
of Institutions reporting
ASSISTANT
PROFESSOR
Salary range of 86%
of Institutions reporting
20
25
30
35
40
45
50
51
55
56
60
61
65
65+
AGE

FIG. 4.

the salaries for each grade of professor fall. Certain assumptions we required; the first of these is that the great majority of Assistant Professors fall within the 25 to 40 age group, Associate Professors in the 30 to 50 age group, and Professors in the 35 to 65 age group.

The limits of the areas shown on Figure 4 were then determined as follows, using the Assistant Professor grade as an example: the lowest of the lower limit of monthly salary, $367, was plotted at age 25 years, and the highest, $667, at 40 years; these two points were then connected. Similarly, the lowest of the upper limit, $478, was plotted against age 25 years, the highest, $939, at 40 years, and these points were connected.

These lines, depicting the lower limits and upper limits, were then cut to include only the figures for the bracket containing the majority of Institutions. The figure was closed at the 25-year end, but left open at the 40 year end, because there are some Assistant Professors beyond this age limit.

In a similar way, areas containing the salaries paid to Associate Professors in 82 per cent of the institutions reporting and Professors in 71 per cent of the schools reporting were plotted. When comparing these faculty salaries with the industrial research salaries, it must not be forgotten that the faculty personnel receive their rate for only nine months, while the research people are paid at their rates for twelve months.

Questions raised regarding Figure 4 have prompted the authors to convert the curve for industrial research salaries so that it shows annual salaries for comparison with the basic annual teaching salaries of engineering faculty. It is felt that Figure 5 may present data in a more informative manner.

Comments

Salary surveys become historical records as soon as the data are collected. Single surveys in themselves do not indicate trends, but show a situation as it exists at a given point in time. Survey figures need to be accumulated from year to year in order that trends can be established which will allow universities to pace themselves and maintain such relationships with industrial research salaries as may be considered expedient.

This presentation can be considered as no more than a rough qualitative approach to the problem. Data for the three areas considered, namely: industrial engineering research, university engineering research, and university engineering teaching, should be collected during a common period and with as much personal contact as possible, rather than by means of questionnaires sent through the mails. The data from all sources should be analyzed on a common basis. It would appear that such a survey could best be conducted during the period beginning July 1 so that the results might be available by the beginning of the calendar year.

It is clearly recognized that the data presented herewith are out of date by now. Experience of the past few years, combined with information as to starting salaries offered 1957 graduates in engineering and science, clearly indicates that industrial research salaries are continuing to rise. The universities are giving serious consideration to both their teaching and research salary scales, and no doubt July 1, 1957 salaries were higher than those shown on the charts appearing with this paper.

Certain facts do appear self-evident. The salaries paid to full-time research personnel by universities are considerably below the industrial scale. Even

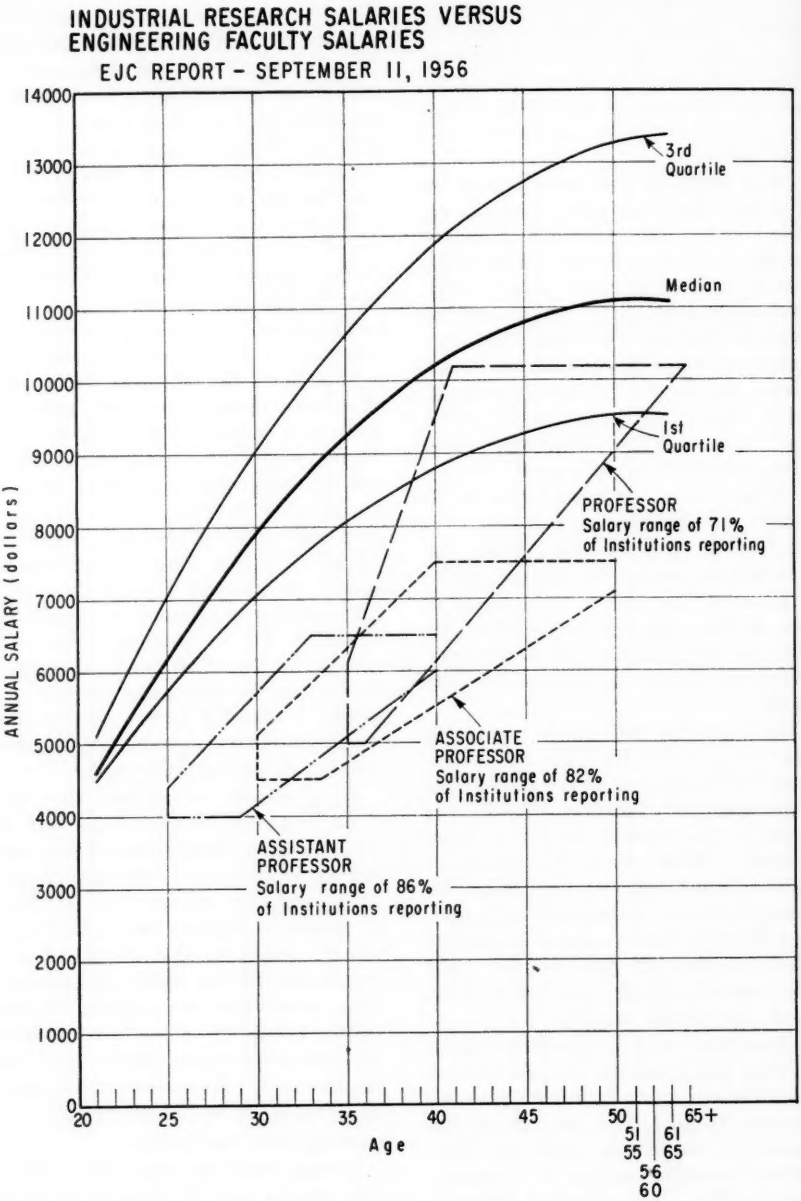
INDUSTRIAL RESEARCH SALARIES VERSUS
ENGINEERING FACULTY SALARIES
EJC REPORT - SEPTEMBER 11, 1956
ANNUAL SALARY (dollars)
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
3rd Quartile
Median
1st Quartile
PROFESSOR
Salary range of 71%
of Institutions reporting
ASSOCIATE
PROFESSOR
Salary range of 82%
of Institutions reporting
ASSISTANT
PROFESSOR
Salary range of 86%
of Institutions reporting
20
25
30
35
40
45
50
51
55
56
60
61
65
65+
Age

FIG. 5.

those institutions having some differential between research and teaching faculty salaries are below the industrial scale. While it is true that university research staff members are presumed to gain much more than pecuniary recompense from their endeavors, the magnitude of the salary differential must have limits.

The university research salaries for those institutions indicating no differential with teaching salaries are decidedly on the low side, while the areas outlined in Figures 4 and 5, particularly for Assistant and Associate Professors, show that most of the salaries are on the low side.

Outside consulting and summer employment for engineering faculty members is often encouraged by the universities as improving teaching ability, but it appears that in many cases this work may be necessary in order for faculty to exist.

The authors do not wish to draw further conclusions from the information available, but hope that those interested in the problems highlighted may obtain some assistance from the data presented.

ANALYSIS OF EDUCATIONAL POTENTIAL IN ENGINEERING COLLEGES

(Continued from page 593)

have no accreditation by ECPD. Of the 22,539 bachelor's degrees granted, 20,200 (89.5%) were awarded by ECPD-accredited schools, which also accounted for 4339 master's degrees (96.7%), and all doctor's degrees in engineering.

There are 14 land-grant colleges in Group I, 5 in Group II, 7 in Group IIa, 20 in Group III, and 6 in Group IV. In this list, the Massachusetts land-grant is divided between the Massachusetts Institute of Technology and the University of Massachusetts.

Table II shows the number of degrees awarded in engineering and the physical sciences for the years 1947–8 through 1954–5. In engineering, the bachelor's degrees awarded have decreased by one-third. In all fields shown the master's degrees awarded have increased little, and in chemistry have actually decreased. The doctorates awarded have about doubled in all fields shown, but the numbers are far below our needs.

With lower numbers of bachelor's degrees being awarded, the likelihood of a substantial increase nationally in master's and doctor's degrees seems not immediate, unless vigorous attention is given to a real strengthening of our schools of engineering and science.

A MINORITY GROUP AS A SOURCE OF ENGINEERING MANPOWER

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Newark College of Engineering

The shortage of engineers of the past several years has been one of the major concerns of the United States. The Engineers Joint Council's Engineering Manpower commission has published a *Newsletter* (1) since 1951 that is devoted largely to this shortage and how to alleviate it. Wolfle's *America's Resources of Specialized Talent* (2), the National Manpower Council's *A Policy for Scientific and Professional Manpower* (3) and The Educational Policies Commission's *Manpower and Education* (4) are some of the works that have dealt with such manpower problems.

The consensus of all sources seems to be that the solution to the problem of supplying engineers is not simply to entice qualified men away from other professions or high-level occupations. It is, rather, that we make the best possible use of the total qualified manpower that this country possesses.

In 1956 Eli Ginzberg's (5) *The Negro Potential* was received with great interest. Ginzberg called attention to the striking under-utilization of the Negro in skilled work and in professional employment.

Starting in 1954 and running through 1956 this author conducted a study (6) of the opportunities for Negroes in engineering. Part of this study—a doctoral dissertation at Rutgers, The State University—supplied the data on which this article is based. The data support the theory that a partial solution of the engineering manpower shortage could come from encouraging more qualified Negro youth to enter the engineering profession.

The U. S. Census figures for 1950 (7) showed that there was one Negro engineer in the United States for approximately 300 white engineers. If the ratio of Negro engineers to white engineers could be brought closer to the one in ten that Negroes represent in our total population, many additional engineers would be available to help alleviate present or future engineering manpower shortages.

Three questions remain to be answered before it can be concluded that Negroes will be of appreciable help in serving our society as engineers. They are:

1. Are there training opportunities for Negroes in our accredited engineering colleges?
2. Are there employment opportunities for Negro engineers?
3. Can today's Negro achieve full professional status in engineering?

Training Opportunities

In June of 1956 a request for information on the numbers of Negro students at each institution was sent to the deans of the 150 ECPD-accredited engineering colleges. The deans were most cooperative in the number and nature of their responses. Of the 150 questionnaires, there were 143 (95%) returns, representing at least one college in each of the 48 states.

Many of the deans stated that it was contrary to college policy, and sometimes to state laws, to keep records according to race; consequently they were handicapped in reporting.

Some therefore supplied information based on the memories of their department heads or on the personal knowledge of registration officials. The most important single fact emerging from the data was that there were Negro students in attendance in at least 73 of the engineering colleges.

There were 108 deans who listed actual numbers of Negro students totaling 454. These students were not distributed evenly among all four years of college. There were 242 (or one to every 152 other students) in the freshman year. The number decreased progressively each year. In the senior year there were 43 such students (or one to every 364 other students).

The questionnaire to the deans contained space for comments. All but two of the many who commented were favorable to the idea of more Negroes entering the engineering profession. An example of the remarks was, "I see no problem, and I can envision no problem." Another stated, "Of course Negroes should be utilized to the fullest extent of their training and capabilities, whether there is a shortage or not." A third stated:

> We would welcome more qualified Negro applicants than we are getting and, if such applicants were forthcoming, they would be admitted, educated, and placed in exactly the same fashion as are all other potential students.

Some of the deans directed their comments to the help that Negro engineers could be in solving manpower shortages. Most were of the opinion that there is a Negro potential that could and should be used. As one dean pointed out, "It could be an important supplement to the engineering manpower shortage if more Negroes would study engineering and enter the profession." Another said: "Any qualified engineer, regardless of race, color, or creed, should be utilized."

The comments quoted above were typical. The two deans who were not enthusiastic, however, expressed the opinion that there would be placement problems with Negro engineering graduates.

Employment Opportunities

Information on employment opportunities for Negro engineers was obtained from industrial firms and from the employment records of Negro engineers. Nineteen companies—the largest in their respective manufacturing fields—were asked for information concerning the number of Negro engineers employed. All nineteen of the companies replied. It was learned that among firms that had over 26,000 engineers, there were between 40 and 65 Negro engineers employed.

Comments of the employers were of three general types. First, the firms emphasized that they kept no record of the race of employees. Second, they stated they were willing to hire Negroes. Third, there was a lack of qualified Negro applicants for the engineering positions.

To supplement this direct response, a second industrial source of information on the employment opportunities of Negro engineers was used. "Help Wanted" advertisements in the newspapers of the 41 largest United States cities were surveyed, and questionnaires were sent to each of 102 firms that had advertised for engineers on the same day across the country. These were smaller firms than those in the first group. The same questions were asked of this group of firms, but, possibly because in this case the replies were anonymous, the information returned was more detailed.

Of the second group of employers, 56 (55%) replied that they employed

15,500 engineers, 81 of whom were Negroes. The comments of these employers were similar to those of the first group. Almost three-quarters of those who commented were favorable to the employment of Negro engineers. Many wrote of the lack of Negro applicants.

Although the total number of Negro engineers employed in both groups of companies was not large (about one for each 500 white engineers for the first group of companies, and one for every 200 in the second group), it is significant that 50% of all of the companies queried were actively interested in Negro engineers as employees. That is, 28% of the companies employ Negro engineers, and 22% more wish to employ them but do not receive applications for employment from them.

The other main source of information on the employment opportunities is the employment records of Negro engineers themselves. A list of 140 such men was obtained from the secretaries of two associations of Negro engineers. Almost all of these men had received one or more engineering degrees between 1899 and 1954. They were revealed as having successful careers in private industry, Civil Service, and in teaching. Every single one of the respondents answered that he would advise qualified Negro youths to choose an engineering career today.

Professional Status

In order to learn if Negro engineers had achieved full professional status, it was first determined that Negroes are members of the chief engineering and professional societies.

The second source of information on the professional status of the Negro in engineering came from answers that the Negro engineers themselves gave to such questions. For 76 Negro engineers who answered that their work had professional status and four who answered that their work was professional "in part," there were only five who stated that their work was not at the professional level. The men who claimed professional status estimated that they achieved this level of work in an average time of less than three years.

Apparently, then, the door *is* open to full membership in the engineering profession for members of the Negro race. Further, there are both training and employment opportunities available at the professional level for Negroes. The members of the minority group therefore represent a potential source of manpower for the alleviation of present or future shortages of engineering talent.

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THE AEC-NSF-ASEE NUCLEAR INSTITUTES

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This article was submitted for publication without solicitation. Everyone under 40 should read it.

During the summers of 1956 and 1957, the American Society for Engineering Education, the National Science Foundation, and the Atomic Energy Commission co-sponsored several nuclear institutes for engineering college teachers. This paper gives some first-hand impressions of the proceedings and reviews the accomplishments of the two schools which I attended, the 1956 Nuclear Engineering Institute at Brookhaven National Laboratory and the 1957 Nuclear Metallurgy Institute at the Ames Laboratory of the Atomic Energy Commission, Iowa State College.

From communications with individuals who participated in other phases of the program, including Nuclear Engineering at Argonne National Laboratory, 1956, and at Brookhaven, 1957; Reactor Theory at Oak Ridge National Laboratory, 1957; Properties and Techniques of Operation of the Argonaut Reactor at Argonne, 1957; Chemical Processing at Hanford, 1957, I believe that my experiences are representative.

In the summer of 1956, 30 college teachers from 21 institutions in the United States and Puerto Rico gathered at Brookhaven National Laboratory for an eight-week course of study. The group was composed of four chemical engineers, three civil engineers, five electrical engineers, six mechanical engineers, seven physicists, four chemists, and one metallurgist. The distribution by academic rank was eight professors, eleven associate professors, eight assistant professors and three instructors. Four of the class members were heads of departments.

Nuclear Engineering

The Nuclear Engineering Institutes are general courses, at the introductory level. At Brookhaven, mornings were devoted to lectures, while laboratory experiments were performed in the afternoons. The two daily lectures were delivered for the most part by members of the permanent Brookhaven staff, although experts from various sections of the country participated in a nuclear reactor symposium held during the seventh and eighth weeks of the course.

Series of talks on major phases of the nuclear power program were given after introductory lectures on nuclear physics. Among major topics covered were reactor physics, health physics, instrumentation, nuclear chemistry, reactor heat transfer, chemical processing of fuels, fission-product utilization, waste disposal, nuclear metallurgy, shielding, and mechanical design. In addition, special topics such as particle accelerators and research reactors were discussed.

In the laboratory, the class was assigned in squads of six and experiments were performed with most of the laboratory facilities available at Brookhaven. The experiments were carefully planned and organized within the framework of the over-all program. Among the topics scheduled were neutron age measurements, exponential assembly measurements, measurements of the flux distribution and disadvantage factor of the Brookhaven reactor, and a period determination of a critical assembly.

In nuclear physics, the cross section of cadmium was determined and neu-

tron diffraction studied. The nuclear engineering experiments involved study of heat transfer, graphite irradiation, uranium microstructure, liquid-metal corrosion, metallic solution activity, liquid-metal filtration and waste-solution processing.

Nuclear chemistry experiments included measurement of half-life, radioactive identification, Co^{60} calibration and radiation polymerization. Two interesting experiments in health physics were instrument calibration and a field exercise in the waste-processing area of the laboratory.

Nuclear Metallurgy

The Nuclear Metallurgy Institute at Iowa State College in 1957 was an advanced course in a more specialized area of the nuclear power program. Twenty men attended the session, representing 17 different institutions scattered throughout 15 states and Puerto Rico.

Of those attending the institute, one was a professor, nine were associate professors, eight were assistant professors, one was a research professor, and one was an instructor. Eight of the men were members of chemistry or chemical engineering departments; one represented mineral and metallurgical engineering; one, metallurgy; two, metallurgical engineering; three, mechanical engineering; one, physics; two, civil engineering; one, mechanics; and one, ceramic engineering.

The course consisted of three lectures every morning and a laboratory exercise each afternoon, for a period of eight weeks. Major lecture topics were nuclear physics, radiochemistry, health physics, solid state physics, analytical chemistry, principles of refractories, principles of extraction, and metallurgy of uranium, niobium, tantalum, zirconium, hafnium, and thorium.

In addition, considerable time was spent on waste disposal, reactor materials, corrosion of fuel elements, and the chemistry of fused salts and rare earths. Solid state physics received major emphasis. Members of the teaching and research staffs of the College and the Ames Laboratory delivered the lectures.

The laboratory experiments were illustrative of all aspects of the lecture material. The class was fortunate in having the opportunity to use or see demonstrated facilities and equipment of the Ames research laboratory.

An indication of the wide variety of experiments performed can be obtained from the following titles: physical and mechanical properties and metallography of uranium and thorium alloys, cathodic etching, specific heat by the pulse method, ultrasonic measurements, interpretation of X-ray powder patterns, mass spectrography, magnetic susceptibility measurements, distribution of impurities by autoradiography, internal friction measurements, simulated column, ion exchange, preparation of uranium metal, internal friction measurements, thermal diffusivity measurements, and instrumental analyses.

Results

Both of these institutes attained their immediate objective, which was the training of engineering college teachers in nuclear science. The outstanding contributions of the Brookhaven institute were the presentation of basic principles of nuclear science, problems inherent in the nuclear power program, and introduction of the student to nuclear terminology and nomenclature.

The Nuclear Metallurgy Institute at Ames performed an excellent service by giving a thorough discussion and evaluation of the metallurgical and reactor material problems in the nu-

clear field. Brookhaven stimulated the men in the group to an interest in the curricular aspects of nuclear science and technology, while Ames helped develop additional background for teaching and research in a specialized area. A large majority of those who attended the institutes are now actively engaged in teaching, research, or the organization of curriculas in nuclear science.

Perhaps the most important conclusion reached by the classes at both institutes is that there is no justification for an undergraduate curriculum leading to a nuclear engineering degree. As a matter of fact, at the conclusion of each institute, no one could agree upon what is meant by "nuclear engineering." The problems in the nuclear field are solved by the same principles which are fundamental to the traditional engineering curricula, with the complication that the unusual properties and reactions of nuclear materials and processes must be considered as well.

Indeed, can there be such a person as a "nuclear engineer?" To my mind, he would have to be an excellent chemical, mechanical, civil, and electrical engineer, as well as a metallurgist and a nuclear physicist, all rolled into one. Consideration of the teamwork required in the solution of past and current nuclear reactor problems, and the composition of these teams indicates that true "nuclear engineers," if they do exist, are few and far between.

Nuclear Teaching

If this conclusion is valid, then the best approach to the teaching of nuclear science and technology on an undergraduate level would be the incorporation into existing curricula of problems relating to the nuclear field. Thus, a course in unit operations of chemical engineering may include solvent extraction of uranium and plutonium from fission products. A mechanics of materials class may well cover some of the properties of reactor materials.

Electrical engineering subjects can cover electromagnetic pumps or some of the reactor control circuits. The unusual heat transfer situations in reactors can be discussed in heat transfer classes. Of course, a suitable background in nuclear science can be introduced by subjects such as nuclear physics, nuclear chemistry, or an introduction to "nuclear engineering."

Advantages of Institutes

It seems essential that more engineering instructors become familiar with basic nuclear science and the manner in which their specific disciplines can be applied to the solution of nuclear problems. The opportunity offered by the Atomic Energy Commission and the American Society for Engineering Education during the past two summers has been a golden one. In anticipation of similar institutes for the immediate future, I strongly urge our engineering instructors, especially the younger ones, to take advantage of the offerings.

Aside from the obvious benefits to the individual and to his institution, attendance at a nuclear institute can improve one's teaching in other respects. For example, the college teacher becomes a regular student again, in some cases for the first time in many years. As a result of being continuously on one side of the podium, many of us lose our perspective. After our experiences at the institutes, those of us who attended feel that we are better conversant with the student's attitudes, and with reasons why a lecture can succeed or fail, than we were two years ago.

Secondly, the diversity of background of the members of the class,

the close and cordial relations that usually develop when most of the class members live together, and the inevitable and frequent informal discussions are bound to broaden one's outlook. Finally, the genuine friendships that are made among the class members and between student and teacher are permanent souvenirs of a summer well spent.

It should be noted that the great difference in background may sometimes work to the disadvantage of the group. The presentation of subject matter must be modified, depending on the past experience of the students. As a result, a few may complain that the material is treated in too elementary a fashion, while others may decry the difficulty of the lectures.

Also, there may be some repetition by different institutes and among lectures at a given institute. But these are difficulties which are outweighed by the advantages enumerated above. Furthermore, with increased numbers of applicants, future classes can undoubtedly be more homogeneous because of the greater selectivity possible in accepting candidates.

In conclusion, it is my opinion that nuclear institutes sponsored by the American Society for Engineering Education are representative of the fine contributions the society has made to engineering education.

COLLEGE ADMINISTRATION INSTITUTE REPEATED

The Institute on College and University Administration at the University of Michigan will be held again this summer from July 7 to 11 inclusive. Objective of the program is to offer present and prospective administrators an opportunity to study together, and with resource leaders, some of the basic problems of college and university administration. Each day will be devoted to some major phase of administration, approached in two ways: (1) presentations by men of unusual experience, and (2) discussion centered upon problems arising from the group. Engineering administrators will be welcomed.

The themes for discussion and the resource leaders will include: curriculum administration, Frank R. Kille; institutional self-studies, Floyd W. Reeves; developmental programs, Paul R. Franz, Jr., and Alan W. MacCarthy; administrative organization and efficiency, H. J. Heneman of the firm Cresap, McCormick and Paget; and trends in higher education affecting administration, Algo D. Henderson, who, with the assistance of James M. Davis, directs the Institute.

The Institute is under the auspices of the Center for the Study of Higher Education at the University. Last July, the enrollment, which was limited to sixty, included 23 presidents or representatives of the president's office, 26 deans, and 11 other persons; total attendance came from 21 states.

WORKTEXT TEACHING AID IN ADVANCED APPLIED MATHEMATICS

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No one need remind us of the rapid rate at which knowledge in all fields is outstripping the ability of individuals to assimilate new information. This is particularly true in the field of advanced applied mathematics. The worktexts described herein were conceived and executed to alleviate the difficulties of incorporating new knowledge into academic programs in mathematical engineering and physics.

The word "worktext" is the contraction of two words, "workbook" and "textbook." The worktext is a textbook that presents developments which extensively utilize incomplete equations for which the student supplies the missing terms. As a workbook, it incorporates the necessary textual material at the given level, so that additional references are not required in working through the theory and examples. Thus the advantages of text and workbook are combined. By completing the omitted portions of the equations, the student learns the textual material and develops manipulative skill.

Since time is of the essence in training technical personnel, a major objective of the worktext is to develop competence in employing a mathematical discipline to a given degree of proficiency in a minimum amount of time. By utilizing worktexts, both to develop skills and to review the student's knowledge, the instructor gains classroom time in which to enrich and expand the subject matter of the course.

Historical Background

The need to institute the worktext method grew out of experience in the Electrical Engineering Department of Illinois Institute of Technology where a three-year program in field theory is offered for graduate students. This program consists of two semesters of advanced electricity and magnetism, two semesters of advanced microwaves, and one semester each of radiation and antenna theory.

As long as these courses were taken in sequence, the required mathematical tools beyond the normal prerequisites could be included in the field theory program. However, with a program of this length, it has not been feasible for everyone to take the courses in the same sequence. In order to have new students start the program each year, without running several overlapping series of courses, it was necessary to remove the prerequisite sequence of the work. Thus, it became impossible to provide the mathematical preliminaries to each course without excessive, time-consuming repetition.

The suggestion naturally arises that students take prerequisite mathematics courses in the mathematics department, and in actuality they are required to do just that. However, the desired material is spread over an unrealistically large number of courses. Furthermore, mastery is rarely gained by a student during his first exposure to a discipline. The worktext supplies the more extended second exposure that is generally needed to gain this mastery, and elaborates particularly pertinent topics. The worktexts are passed out as supplementary assignments required of all field theory students who have not previously completed them. Satisfactory com-

pletion of the worktexts goes a substantial distance toward providing an adequate working facilitiy with the mathematics utilized in the field theory program. An additional benefit is that the worktext familiarizes the students with a single, systematic notational scheme.

Worktexts were instituted for the first time in 1952. Students received the assignment very favorably, in spite of the extra load it appeared to entail. The use of worktexts clearly increased their accumulation of knowledge and comprehension per unit time, and gave them a greater sense of accomplishment. Many former students and other individuals requested copies of the worktexts for their own use as a review, applicable to current on-the-job problems.

To date the following worktexts have been prepared and utilized:

1) Vector Analysis Worktext *	422 pages
2) Orthogonal Series Worktext	48 pages
3) Fourier Analysis Worktext	143 pages
4) Matrix Theory Worktext	83 pages
5) Product Expansion Worktext	55 pages
6) Function Integral Worktext	28 pages
7) Bessel Function Worktext	59 pages
8) Associated Legendre Function Worktext	48 pages
9) Transmission Line Worktext **	128 pages

In choosing the topics for which worktexts were written the following points were considered:

1) The subject matter should be common to more than one of the graduate courses,

2) The subject matter should be such that the average graduate student has an inadequate command of it, even though he may have been exposed to it in prerequisite courses,

3) The subject matter should be such that a command of it is essential for achieving adequate grasp of the course material.

Worktexts designed to serve the needs thus indicated greatly reduce overlap between courses and free class time for a broader and deeper pursuit of the subject matter.

In writing the worktexts special emphasis was given to:

1) The manner in which mathematical constructs are abstracted from a set of physical situations. Understanding this procedure greatly aids the student in realizing the physical significance and utility of the mathematics.

2) Avoidance of oversimplification, which leaves the student in the dark when he encounters other problems involving details previously passed over.

3) Inclusion of an adequate number of steps so that the student does not have to pursue several blind alleys. The student's time is far more valuable than the extra paper required for printing.

During the summers of 1956 and 1957 an experimental three-semester-hour course was given, based on worktexts. The 1956 course utilized:

1. Vector Analysis Worktext	317 pages
2. Fourier Analysis Worktext	143 pages
3. Bessel Function Worktext	59 pages
4. Function Theory Worktext	48 pages
	567 pages

* A short excerpt of this worktext is shown in the Appendix.

** Although transmission line theory may not be considered a formal branch of applied mathematics, it follows the same presentational format and serves the same philosophical objectives; therefore, it has been included here.

The 1957 summer course contained:

1. Vector Analysis Worktext	422 pages
2. Matrix Theory Worktext	83 pages
3. Product Expansion Worktext	55 pages
4. Function Integral Worktext	28 pages
5. Bessel Function Worktext	59 pages
6. Associated Legendre Function Worktext	48 pages
	691 pages

The courses were conducted in the following manner. Approximately 70 to 90 pages of worktext per week were assigned. No formal lectures were given. One three-hour period each week was devoted to an examination covering the material assigned the previous week. A second meeting each week was devoted to going over the examination in class. At the end of the course the students were asked to fill in a questionnaire of the form shown below.

EE 597 QUESTIONNAIRE 14 August 1957

In order to formulate some concept of the relative value of the worktext as a teaching aid, it would be greatly appreciated if you would evaluate the following ratios, as objectively as possible, based on your personal experience.

How does this course based on worktexts compare with other courses based on conventional lecture and study methods, with regard to the following items:

ABBREVIATIONS: PUTPIBSI = per unit time put in by student in
WC = worktext course
CC = conventional course

a) $\dfrac{\text{Material covered} - \text{PUTPIBSI-WC}}{\text{Material covered} - \text{PUTPIBSI-CC}} =$

b) $\dfrac{\text{Material Learned} - \text{PUTPIBSI-WC}}{\text{Material Learned} - \text{PUTPIBSI-CC}} =$

c) $\dfrac{\text{Manipulative skill developed} - \text{PUTPIBSI-WC}}{\text{Manipulative skill developed} - \text{PUTPIBSI-CC}} =$

d) $\dfrac{\text{Comprehension developed} - \text{PUTPIBSI-WC}}{\text{Comprehension developed} - \text{PUTPIBSI-CC}} =$

e) $\dfrac{\text{Material covered by worktext course}}{\text{Material covered by average conventional 3 hr. course}} =$

The average values for these ratios as given by the 1956 and 1957 groups were:

	1956	1957
a	2.3	2.3
b	1.9	1.7
c	2.2	2.9
d	1.5	1.3
e	—	2.5

The following tables show the answers of the individual students and are ordered according to the students examination performance standing in the class.

1956 Summer Course Data

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
% Grade	66	66	62	57	55	54	54	53	53	53	51	51	50	50	49	49	45	45
a	1.5	1	4	3	2	3.5	1.5	1	3	3	2	1	3	1	6.5	2	2	0.5
b	1.5	1.5	3	5	3	1	1.8	2	1	0.5	2	1	1	0.5	6.5	1.75	1	0.5
c	2	1	4	2	3	3	2	4	0.5	1	2	2	2	2	2.5	3.5	0.5	3
d	1.5	2	3	—	1	1.1	1.2	3	2	0.5	3	1	1	0.5	6.5	2	0.7	0.5

1957 Summer Course Data

	1	2	3	4	5	6	7	8	9	10	11	12
% Grade	68	62	60	54	53	50	46	46	43	41	41	38
a	7	2	1.5	1	1.2	3	4.5	1	1.5	1	1.5	2
b	2	3	1.5	1.5	1.4	1.5	3	2	1.5	1	0.5	2
c	5	10	2	2	1.2	1	3.5	2	2	2	3	1.5
d	1	3	1.1	0.5	1.1	2.5	0.5	1	1.5	0.5	1	1.7
e	2.5	3	2.5	3	3	2	2.5	2	3	3	3	2

Concluding Remarks

Although no objective statistics are available to illustrate the effectiveness of the worktexts, the subjective statistics collected from the students participating in the courses indicate that on the average

a) 2.3 times as much material is covered per unit of time by using the worktexts as by conventional methods,
b) 1.8 times as much material is learned per unit of time by using the worktext as by conventional methods,
c) 2.4 times as much manipulative skill is developed per unit of time by using the worktext as by conventional methods,
d) 1.4 times as much comprehension is developed per unit of time by using the worktexts as by conventional methods.

These results were obtained with worktexts that were far from optimum. Improvements in the worktexts should lead to corresponding improvements in their effectiveness.

It would be desirable to test the effectiveness of the worktext as a teaching tool by setting up an experiment in which a control group, using conventional methods, serves as a

gage of the level of competence reached by a group employing the worktexts. This has not yet been feasible. However, experience suggests that the worktext not only saves the student time in mastering a given amount of material, but saves the instructor time in checking the student's work.

The author would be pleased to hear from anyone interested in these worktexts.

APPENDIX

Illustration of Worktext Material

CHAPTER XI VECTOR ANALYSIS WORKTEXT G.I. COHN
EE Dept. IIT

(204) $\nabla 1_r = (1_r\partial_r + \quad)1_r =$

(205) $\nabla 1_\theta =$

(206) $\nabla 1_\phi =$

Gradients of Vectors

In a general orthogonal coordinate system the gradient of a vector may be expressed as

(207) $\nabla \mathbf{a} = \nabla(1_1 a_1 + 1_2 a_2 +$

Distributing the gradient operation gives

(208) $\nabla \mathbf{a} = \begin{matrix}(\nabla a_1)1_1 + \\ + a_1 \nabla 1_1 + \end{matrix}$

To preserve the dyad, the order of the unit vectors in an outer product must not be interchanged. In this case the unit vectors of the ∇ must remain on the left and the unit vectors of $\mathbf{a}$ must remain on the right in each product.

In order to save writing, it is convenient to break the evaluation of the gradient of a vector into two parts. Thus,

(209) $\nabla \mathbf{a} = \nabla \mathbf{a}\big|_{\substack{\text{unit vectors} \\ \text{held fixed}}} + \nabla \mathbf{a}\big|_{\substack{\text{scalar components} \\ \text{held fixed}}}$

Hence,

(210) $\nabla \big| \mathbf{a}_{\substack{\text{unit vectors} \\ \text{held fixed}}} = (\nabla a_1)1_1 +$

(211) $\nabla \mathbf{a}\big|_{\substack{\text{scalar components} \\ \text{held fixed}}} = a_1 \nabla 1_1 +$

Example: As an exercise, evaluate the gradient of a vector in spherical coordinates. In spherical coordinates

(225) $\nabla \mathbf{a}\big|_{\substack{\text{unit vectors} \\ \text{held fixed}}} = \begin{matrix}[(1_r\partial_r + \quad)a_r]1_r \\ + [\quad\quad\quad\quad\quad\quad\quad\quad)a_\theta \\ +\end{matrix}$

Distributing components and introducing unit dyad notation gives

$$\nabla = 1_{rr}\partial_r a_r + \tag{226}$$

The contribution to the gradient from the variability of the unit vectors is

$$\nabla \mathbf{a}\Big|_{\substack{\text{scalar components}\\ \text{held fixed}}} = a_r \nabla 1_r + a_\theta \nabla + \tag{227}$$

Using (204) thru (206) to evaluate (227) gives

$$\nabla = a_r(1_{\theta\theta} + a_\theta \tag{228}$$

Combining (226) and (228) gives for the gradient of a vector in spherical coordinates

$$\nabla \mathbf{a} = 1_{rr}\partial_r a_r + 1_{\theta r} + 1_{\phi r} + \tag{229}$$

ASEE CALENDAR OF EVENTS

Meeting	*Date*	*Location*	*Chairman or Information*
Southwestern Section	April 3–4	Southern Methodist University	A. R. Burgess, Texas A. & M. College
Missouri-Arkansas Section	April 12, 1958	Washington University, St. Louis, Mo.	L. Gilbransen, Washington U.
Ohio Section	April 19	Ohio State University	M. L. Smith, Ohio State University
Southeastern Section	April 17–18	University of Miami, Florida	L. H. Johnson, Tulane University
Allegheny Section	April 18–19	West Virginia University	R. D. Slonneger, West Virginia U.
Executive Board Meeting	April 17–19	Miami, Florida	Leighton W. Collins, Urbana, Illinois
Rocky Mt. Section	April 26	Colorado School of Mines Univ. of Detroit	F. Campbell, Colorado School of Mines

MANNING AND TRAINING FOR THE DRESDEN NUCLEAR POWER STATION

HAROLD G. CARSON

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Adapted from a paper presented at the Conference of the Atomic Energy Education Committee, 65th Annual Meeting of ASEE, Cornell University, Ithaca, New York, June 19, 1957.

Commonwealth Edison Company and its associate, the Public Service Company of Northern Illinois, entered the field of atomic energy in 1951. No one thought that we would have an atomic plant under construction in 1957, for which a substantial complement of trained operating personnel would be required by 1959.

On the other hand, our management, who had been following nuclear developments since 1947, were certain that the application of nuclear fuel to the generation of electricity was a future certainty and we planned for this revolutionary transition. Thus in 1950, a group of executives and engineers were given a 16-week lecture course on the unclassified aspects of nuclear energy. I think it is of interest to note that one of the lecturers for this course, presented by the University of Chicago, was Enrico Fermi.

AEC Study Team Program

At the same time, members of the Atomic Energy Commission were pondering about "Means of Widening Industrial Participation in Atomic Energy Development." The Commission's efforts resulted in the well-known program of establishing industrial study teams that were authorized to "study the feasibility of developing and operating nuclear reactors for the production of plutonium and other important materials, together with power."

It was through this program, which for us became effective in April of 1951 through an agreement with the Commission, that our group took their first major step into the classified or Secret area to learn how nuclear fuel could be used to provide electricity. In addition, this study team program provided a realistic opportunity to begin training men in the nuclear field. These included not only engineering and technical, but also accounting, financial and executive personnel.

We next employed a nuclear physicist and reactor engineer (Dr. Lyle Borst) as a consultant. He put the group through an intensive course in Nuclear Physics and Reactor Technology. This included both theory and actual practice in terms of "paper" designs and estimates.

Progress of the Team

Results were well beyond expectations. By the end of the year the team's first report was completed, with a detailed design and economic evaluation for a gas-cooled, graphite-moderated 350 megawatt reactor coupled to a power plant having a net electrical output of 45 megawatts.

Expanding the Study Team Effort

The Study Team was conducted on a basis of rotating selected personnel in and out of the group. To date, 23 individuals have spent an average of 16 months on nuclear work. The

value of this experience is best illustrated by mentioning that our present Vice President in Charge of Engineering, our Director of Purchases, and five of the twelve top people who will run our Dresden Station are alumni of the Study Team.

In 1955, Commonwealth Edison Company (Public Service Company having merged with it in 1953) joined forces with seven other companies to form the Nuclear Power Group. Each of these member companies assigns one or more selected engineers to the Study Team, where they participate actively in the work of analyzing, evaluating, and designing various types of nuclear reactors and associated generating facilities.

In addition, selected men of exceptional potential are sent to the Oak Ridge School of Reactor Technology and are lent to various AEC laboratories for even broader training in nuclear work. This, briefly, was our major approach up to the time Commonwealth and its NPG associates made a proposal to the AEC to build a full scale nuclear power plant.

Specific Power Plant Training

We contracted with General Electric Company in 1955 to build the Dresden Station for $45,000,000. The contract specified a completion date of 1960 and provided, among other things, for the planning and execution of a specific training program well in advance of the start-up period.

Because the nuclear part of the plant was new to us, we drew on the experience of General Electric for this, depending on our own background to formulate the organization and training plans for the conventional part of the installation.

We expect to use four media for this training, with each job classification being assigned a specific training schedule. The four means are:

1. Prepared training manuals, lectures and specialized courses.
2. Limited operating practice on the Argonne National Laboratory boiling water reactor.
3. More intensive operating practice on General Electric Company's pilot plant boiling water reactor, now under construction at Vallecitos, California, and
4. On-the-job training at Dresden during construction and first stages of trial operation.

The program began last March for certain groups, with indoctrination courses and nuclear power studies. The training is scheduled over a period of about 34 months, with the requirements for some positions as long as 16 months, and the minimum at about 4 months. On completion of training, about 21 of the operating personnel should be qualified to receive an AEC operating license for the Dresden reactor. This training program is a big undertaking and is estimated to cost approximately $700,000.

Formalizing the Program

With these objectives established, we worked with the General Electric Company to prepare a comprehensive program tailored to the specific group needs.

The class lectures which started in Chicago in March and are now proceeding in Vallecitos, California, were given by personnel responsible for the design and construction of the Dresden plant. The material covered progress reports and included technical explanations and discussions tailored to the needs of the personnel in attendance. Such meetings will continue as long as a need exists.

As an example of the type of material presented, the first orientation talk included a discussion of contract provisions, technical details, and construc-

tion progress briefly summarized as follows:

As mentioned previously, this was a fixed-price contract with General Electric to build the 180,000 kilowatt Dresden Station for $45,000,000. Bechtel Corporation is the engineer-constructor.

One-third of the contract price, or $15,000,000, is being paid as research and development expense over a period of five years by the eight companies comprising our Nuclear Power Group. The remaining $30,000,000, plus the site and overhead costs, will be paid for and capitalized by Commonwealth, which will own and operate the plant.

The research expense assumed by the NPG partners was distributed as follows: American Gas and Electric Service Corporation, Commonwealth Edison, and Pacific Gas and Electric Company, each $2,833,333; Union Electric Company, $2,000,000; Illinois Power Company and Kansas City Power and Light Company, each $1,500,000; Bechtel Corporation, $1,000,000; and Central Illinois Light Company, $500,000.

By disregarding the $15,000,000 of research contributions, we estimate that the plant will ultimately produce power at a cost, including fixed charges, operating expense, and nuclear fuel, of about ¾ of a cent per kilowatthour. This is about the same as the cost of power produced by our newest coal-fired plants.

If the $15 million of research were included, the *estimated* power cost would be about 1¢ per kilowatthour, or one-third higher than the cost of power from our conventional facilities.

Station Specifications

Today we have reached a point in our design where the *reactor enclosure* plans have been released for competitive bidding. This structure will be a steel sphere 190 feet in diameter with the equator elevated 56 feet above grade.

The enclosure will be designed for an internal pressure of 29.5 psig with a temperature rise of 250° F. plus snow and wind loads. The plate thickness will vary from 1.25 to 1.40 inches. The structure will be pneumatically leak tested at 37 psig to assure that it can contain all the radioactive products of any foreseeable incident.

The reactor and its auxiliaries are installed in the sphere, with the turbine-generator and its auxiliaries in the turbine building external to the sphere. The major items of *equipment* in the reactor building or package include the reactor vessel, the primary steam drum, secondary steam generators, the recirculating pumps, and the main biological shielding. The *turbine-generator* unit, the control room, demineralizer equipment, and the usual turbine room auxiliaries are in the turbine building.

The reactor *vessel*, 42 feet high by 12 feet in diameter, will be made of 5½ inch steel, internally clad with ⅜-inch, 304 L stainless steel. The head closure permits access for changing the complete core and control assemblies if this becomes necessary. Cooling water enters the vessel through four 24-inch inlets and the steam-water mixture leaves through twelve 16-inch outlets located near the top of the vessel.

The reactor core is cylindrical in shape, 10½ feet in diameter and 10.0 feet long. It will contain 488 fuel assemblies, in channels about 3¾ inches square, each assembly containing 36 rods, ½ inch in diameter and nine feet long. Each rod consists of many sintered uranium dioxide pellets ½ inch in diameter by ½ inch thick. The channels and the rod cladding

are Zircaloy-2. Approximately 67 tons of 1.5% enriched uranium oxide will constitute a core loading.

Procurement of *equipment* and *services* is proceeding most encouragingly. Contracts have been let for all the major equipment, the turbine-generator, sub-station, load centers, steam drums and secondary generators, pumps, heaters, main condenser, and the concrete, steel, excavating, and grading. General Electric Company's commitments for Dresden and associated testing facilities are now about $25,000,000.

Our work is progressing on schedule, with *design* more than 40% complete, and construction has been started on many of the above components. Preliminary work at the site is also well along; the dedication ceremony in early June marked the start of major construction.

Operation-Training Program

In setting up the plant organization it seemed desirable to parallel, as far as possible, functional structures already existing in the most modern generating stations of the Commonwealth system. For example, the Company policy of training a man to fill a given plant position in whatever station may require a man so skilled was one of the objectives.

With due consideration to nuclear characteristics, the first nuclear power station in our system will have a management staff of 19, plus an employee group of 83. These 102 employees are divided into five general groups, technical, maintenance, electrical, shift operations, and office and stores.

There will be a *Station Superintendent* and his Assistant, supported by a management technical staff of six engineers. The head of the technical staff, designated a supervising engineer, directs the efforts of several specialists such as a radiation protection engineer, chemical engineer, thermal engineer, nuclear engineer, and an instrument and control engineer.

While we have used the word "specialist," it should be understood that this group works as a team, with much training in common. Twenty employees will make up the work force for these specialists.

At the operating level there will be a Maintenance Superintendent with three foremen, an Electrical Superintendent, five Shift Operating Superintendents, and an Office Superintendent. (Incidentally, the Electrical Superintendent has been working with General Electric Company on the electric design detail for the past two years.)

Employees in the mechanical and electrical maintenance work will number 10. There will be 28 people under the Shift Superintendents. A pool of 5 station men is available to both the electrical and maintenance departments, when required. Office employees, watchmen, and storekeepers will add 20 more.

Detailed job descriptions were prepared for each significant position in the plant. From these and from the station's design details and characteristics, a comprehensive operating training program was evolved for all personnel.

I wish to emphasize that three *general areas* must be carefully and thoroughly covered. The men must have some preparatory and academic study, on-the-job training and, lastly, certain individuals must be prepared to take the AEC's tests for Operator Licenses.

All of the plant management personnel were to be given a basic course in the nuclear field. Selected books, pamphlets and AEC regulations were procured for home study and a course in the elements of nuclear power was presented.

As reported, key people, such as

the Superintendent, Assistant Superintendent, and the Technical Staff were then given an intensive and comprehensive course confined specifically to the technology part of the program, the reactor plant designers serving as instructors.

All personnel requiring on-site training will be provided adequate information about the station design and equipment and radiation protection so that they can safely start and operate the plant.

Selecting Trainees

While the training program was being developed, personnel records were examined to find management employees for all administrative and technical positions. Methods of filling other positions have not been determined.

Because of the technical aspects of the work, qualifications started with at least a B.S. degree or equivalent and some operating experience. While a college degree was preferred, plant operating experience was given considerable weight.

Basic Nuclear Training

In February, 1957, the initial group reported for the first meeting of the Basic Nuclear Training Course, and for five weeks thereafter, these men completed reading assignments at home and attended eight hours of scheduled lectures each Tuesday and Thursday. They continued their regular work when not in classes.

They were given instruction in the nucleus of the atom, mass and energy in nuclear reactions, reactor physics, problems in reactor design, instruments and control, health physics, and nuclear energy power plants. To close their basic training, these trainees were given a capsule review in differential equations for two days, five hours each day.

Dresden Station Technology Course

This same group of management and technical people was sent to the Atomic Products Division of the General Electric Company on May 5 to enter training in the Dresden Station Technology Course. Seven weeks were allocated, eight hours a day, for a total of 180 class hours plus whatever time would be necessary in after-hours to do their problems and complete their daily assignments.

This program, as planned, is being conducted by the designers at the General Electric Company's San Jose plant in the subjects of nuclear engineering, differential equations, heat transfer, instrumentation, shielding, heat balance, stress analysis, radiation effects, safeguards, materials, and seven days of equipment description.

Recent reports indicate excellent results from this effort, everyone apparently being motivated by a driving desire to master Dresden Nuclear Power Station in all of its new and fascinating ramifications. This was a big challenge for the group.

By the end of June the students will have returned to Chicago. Some will start preparation of the training program for additional plant personnel and some will take further training at the Commission's laboratories and the Robert A. Taft Sanitary Engineering Center at Cincinnati, or will go back to our stations for further conventional operating experience.

On-The-Job Training

Another part of the training program, the on-the-job phase, provides for the assignment of certain selected plant personnel to work with the staff operating Argonne's Experimental Boiling Water Reactor near Lemont, Illinois, and General Electric's Boiling Water Reactor near Vallecitos, California. Trainees will perform duties

similar to those of their forthcoming assignments at Dresden.

This experience-gathering is expected to require two to three months for each individual.

Operator's License Training

Preparation of Dresden's reactor operators for their licenses is necessary to assure that they will meet the Atomic Energy Commission's regulatory requirements. At present, the three main requirements are a physical examination, a written examination on reactor operation, and demonstrated proficiency in reactor operation.

This portion of the training program will be implemented in sufficient time to prepare these men for the start-up date, now set as December, 1959.

To obtain licenses, the operators must thoroughly understand all routine and emergency operation procedures. They must be thoroughly acquainted with all of the reactor instrumentation. Finally, the operating proficiency of the personnel will be observed by an AEC representative during "dry runs" at Dresden before the initial start-up. As indicated previously, 21 of these individuals will eventually have the responsibility for operating or supervising operation of the reactor.

Coordinated Training

A simplified control sheet was developed which showed the most important items of timing and follow-up for each plant position. With this useful device we have set flexible target dates for every man and every manual. From the Station Superintendent to the last mechanic, from the preparation of the first training outline to the preparation of the final Operating Procedures, the Dresden Nuclear Power Station training activity has been planned on schedule. With the best possible physical plant manned by people prepared as thoroughly as careful deliberation, planning, and application can direct, we are confident that the Dresden Nuclear Power Station will be operated successfully and economically.

MORE FRENCH ENGINEERS?

The French government, hoping to motivate more students toward technical careers, is considering a broad plan to democratize and modernize the school systems. The classics and humanities have always enjoyed higher prestige in France than have technical studies, and the children of workers and lower middle class families have had few educational opportunities. Efforts to change these conditions may increase the numbers of French engineers, which now measure 90 per million of population in contrast to 195 per million in this country and 236 per million in Soviet Russia.

AEROELASTICITY AND ITS INCREASING IMPORTANCE

For Engineering Education

CHARLES E. JACKSON

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Revised and adapted from a paper presented at the Aeronautical Division Conference, June 27, 1956.

It is evident that the field of aeroelasticity encompasses problems which arise from the flexibility of aircraft structures. These range from the static phenomena of aileron reversal and wing divergence to the dynamic problems of flutter and loads resulting from gust encounters and landings. Furthermore, experience has shown that the greatly increased flexibility associated with today's airplanes has, in many cases, made this a more important design consideration than strength.

Bisplinghoff, in his Wright Brothers Lecture, Reference (1), illustrated very clearly the trends toward increasing flexibility in airplane design. He also identified the tendency toward increasing ratios of wing length to thickness, which he calls "slenderness ratios," as a major reason for this trend.

Wing Slenderness and Flexibility

The increase in wing slenderness is largely the result of substantial reductions in the wing thickness that have been made in order to provide the low aerodynamic drag necessary for the high speed operation of current aircraft. In high subsonic speed aircraft, thickness ratios of about twelve per cent were common. In today's high performance aircraft, primary consideration is being given to thickness ratios of about three per cent, with even lower thickness ratios often considered and discarded due, primarily, to flexibility effects.

A principal effect of reduced thickness ratio is the reduction in torsional rigidity associated with a given strength. A major problem encountered with this decreased rigidity on thin wing designs is prevention of wing flutter. The significance of flutter on airplane design is illustrated by Figure 1. This Figure shows, for a typical bomber design, the flutter margin (over the 15% required by the ANC-12 specification) of a wing designed for strength (using the required 50% strength safety factor).

The shaded area shows the estimated range of margins that would be obtained by moderately varying geometric and structural characteristics of the clean wing. Also shown is the detrimental effect resulting from improperly locating the wing-mounted nacelles. Incidentally, it has been shown that the flutter speed may be very sensitive to nacelle position, par-

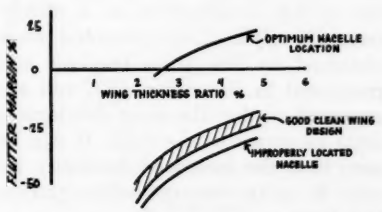

Fig. 1 The effect of thickness on the flutter margin of typical strength-designed bomber wings.

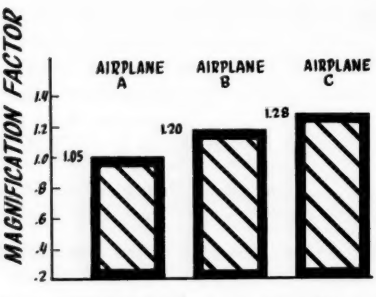

Fig. 2. The effect of wing flexibility on the root magnification factor (data from reference 2).

ticularly in the vicinity of the optimum location, which may be close to a very poor one. It can be seen that the trend toward decreasing thickness ratios is also detrimental flutterwise. Furthermore, considerable benefit can be realized by properly positioning the nacelles for each given case. Accurate analyses must of course be made to determine the best location for external weights.

Another problem which results from wing flexibility is the elastic response of an airplane in a gust. Figure 2 illustrates the significance of wing flexibility on the theoretical average magnification factor experienced at the root of three airplane wings during encounters of vertical gusts with sine shapes of various wave lengths. Magnification factor here is defined as the root bending moment per g. c.g. acceleration experienced in the gust, divided by the root bending moment per g. c.g. acceleration in a steady maneuver. The data presented were obtained by Mr. John Houbolt and presented in Reference (2), and are arranged so that the wing slenderness ratio increases to the right. It can be seen that the increased flexibility results in an increasing root magnification factor.

To pursue this line a little further, the results of a study of the spanwise variation of magnification factor are shown in Figure 3. Appreciable increase in this factor is shown for the outboard locations. It is worth while to mention that this spanwise distribution of magnification factor is apparently caused by the fact that the wing's first bending response is predominant. If higher bending mode response had been significant, the curve would probably have peaked at some intermediate spanwise location. From the above, one can conclude that any attempt to neglect the effect of flexibility in determination of wing loads induced by gusts for the configuration studied would result in a totally unrealistic picture of the magnitude of these loads.

In addition to the problems mentioned above, aeroelastic phenomena profoundly influence stability and control. Imagine, for example, how little stabilizing effect a horizontal tail would have on the end of a long flexible body. As the airplane was pitched up, the load on the horizontal tail would bend the fuselage, decreasing the tail angle of attack and, therefore, the balancing lift load. For airplane control, the change from ailerons to spoilers has been promoted, to a large extent, by attempts to eliminate the problem of approaching aileron reversal at transonic speeds.

Finally, I would like to point out that problems of automatic control and autopilot design, while not included in the field of aeroelasticity, are clearly and directly influenced by aeroelastic considerations. For example, the effects of structural flexibility and unsteady aerodynamics must often be included when describing the airframe part of the system feed-back loop.

The problems of aeroelasticity have become more and more demanding. These demands have come in two ways. First, as I have tried to point

out in the preceding paragraphs, the trend in aircraft design is such that aeroelastic phenomena have become a significant part of the design requirements related to the configuration of the airplane geometrically and structurally. Second, the trend in aircraft design has been such as to make the prediction of these aeroelastic phenomena increasingly difficult.

Flutter

An excellent example of the above mentioned state is the problem of flutter. The present requirement for the flutter margin is that the critical flutter speed be at least 15% greater than the airplane design speed. In the pre-transonic airplane days every effort was made to be conservative in analyzing for flutter, so that actual margins were expected to be in excess of the required 15%. This practice was acceptable because it resulted in little or no cost in airplane weight.

As these conservative estimates began to result in larger weight penalties, reviews of analysis techniques and attempts to improve accuracy were made. It was discovered that even techniques generally thought of as conservative in the past were, in some cases, unconservative. Even the "refined" techniques that were developed often did not yield satisfactory results.

As a result, there are today some airplanes that have encountered flutter in flight and, consequently, are speed-limited to something less than their theoretical capabilities. While this might not appear to be a bad situation, I hasten to point out that flutter is a violent phenomenon which may result in a structural failure. Furthermore, even when the flutter speed of an airplane has been determined, it may require extensive redesign to correct.

This factor would all but rule out an early fix on an airplane which is being produced at a high rate and for which parts are designed and fabricated perhaps a year before the airplane on which they are to be used is completed. The ability to do accurate flutter analysis which would have assisted in selecting the best configuration in the design stages would have kept these airplanes from being seriously restricted.

The demands for increases in both quantity and quality of predictions of aeroelastic phenomena are rising and will continue to rise. To meet this demand, the aeronautical engineering schools should increase emphasis on aeroelasticity. There is no need to point out the fact that this field is currently being somewhat neglected. A close review would, I believe, reveal only a small percentage, if any, of the total course work in aeronautical engineering given to subjects in aeroelasticity. In fact, the dynamic aspects of the field are often shunned immediately by eliminating from basic aerodynamic courses any consideration of unsteady flow. Moreover, comparatively few of the courses taught in aircraft loads or in stability and control introduce the idea that these characteristics are influenced greatly by airplane flexibility.

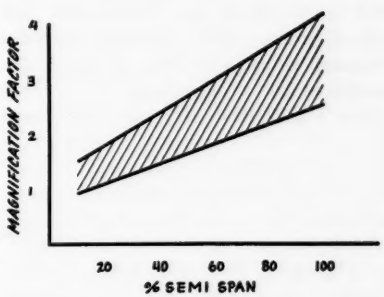

Fig. 3. The spanwise variation of the magnification factor of a bomber airplane.

The curriculum of aeronautical engineering schools today needs to be changed to provide engineering graduates with an understanding of the important field of aeroelasticity. New options need to be inaugurated to provide an adequate output of specialists in the field. I strongly urge that each school try to broaden substantially its course efforts in the field of aeroelasticity for both undergraduate and graduate students. Schools that have already installed aeroelasticity courses in their curricula are to be commended and urged to increase their efforts. Those schools that have no such courses are, I feel, overlooking a vital part of their student's education.

Proposed Educational Program

As a goal, an ambitious but realistic program would begin with the overhauling of present aerodynamics, loads, and stability and control courses to include unsteady aerodynamics and structural flexibility effects where appropriate. While one might argue that to do this some of the essential course matter would have to be dropped, I feel that a review of current course matter would result in the elimination of a sufficient amount of obsolete work to permit the inclusion of studies of such vital things as the effects of flexibility on wing lift distribution and horizontal tail effectiveness, and unsteady aerodynamics produced due to gust encounters and wing vibration response. Also, I feel that at least one course of approximately three semester hours in aircraft dynamics, and an aeroelasticity laboratory of approximately two semester hours, should be installed as required undergraduate studies. In addition, sufficient optional course work should be offered so that both undergraduate and graduate students could specialize in the field. The adoption of a program such as the one above by a substantial number of schools, together with faculty encouragement of students to enter the field of aeroelasticity, should do a great deal toward fulfilling the need for trained personnel.

The problems of accomplishing such an ambitious program will, of course, be sizeable. The need of the aircraft industries for people with backgrounds such as I have described is acute, however. This essentially unlimited opportunity for graduate engineers trained in the field should provide the incentive necessary to the aeronautical engineering schools. Engineers and educators must work together in solving the problems and producing trained engineers who appreciate the increasing importance of aeroelasticity and who are able to work in and contribute to the field.

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SOME STRESS ANALYSIS PROBLEMS OF CURRENT HIGH-SPEED FIGHTER AIRCRAFT

And Their Educational Implications

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The tremendous strides made in aircraft performance during the past few years have created many problems for all aeronautical engineers, and the aircraft stress analyst is certainly no exception. Fighter speeds have more than doubled in the past decade. This has not only introduced such problems as transonic load distribution and aerodynamic heating, and aggravated other problems such as aeroelasticity and panel fatigue, but has also created countless additional problems due to the configurations required to attain these high speeds.

Extremely thin, highly swept wings, all-movable stabilizers, very large, dense fuselages, and tremendous power plants are a few of the major configuration changes which create problems of both external and internal load distribution for the stress analyst. Another less clear-cut but probably more important structural problem that must necessarily be linked to required configuration changes is the increased structural efficiency required to obtain these tremendous performance improvements. It is important to remember that these gains have been made in spite of the increasing demands on the structure due to the required environmental and configurational changes. A decade ago, the structural weight accounted for 30% to 40% of the total takeoff weight, against 20% to 30% today.

Gains in structural efficiency coupled with the problems inherent in increased performance place an ever-increasing load on the aircraft stress analyst. The purpose of this paper is to discuss some of these practical, less familiar problems of the stress analyst engaged in designing today's high speed fighter aircraft and to comment briefly on the educational needs of the young engineer who must find solutions to these problems.

Loads

Some years ago, it was fairly common practice to have one or two stress engineers spend a month or two writing a loads report for a new model fighter. These reports were simple, used many rules of thumb, made some very crude and often conservative assumptions, but in general were quite satisfactory for the subsonic, straight-winged, conventional fighter configurations of that period. As fighters entered the transonic range, however, it became apparent that the crude, simple methods would either have to become very conservative in order to encompass all possible combinations of variables or become considerably more refined and time consuming.

During the same period, the swept

wing arrived on the scene with all of its variations to the aerodynamic coefficients important to the derivation of external loads. These events started a gradual change in the manpower division between stress analysis and loads analysis and today it is estimated that 25% of the total stress analysis effort is directly spent on the derivation of external loads.

The problem of wing spanwise load distribution is one of the most important and difficult problems that the loads engineer must solve. He must estimate the rigid load distributions throughout the Mach number range based on measured over-all airplane coefficients, low speed theory, supersonic theory, and limited wind tunnel data gathered on similar models by the N.A.C.A. Unfortunately, no satisfactory transonic theory exists today, and many times this flight regime proves to be the most critical. Since the airplanes are not rigid, the effects of deflected aerodynamic surfaces on the aerodynamic characteristics must be considered to arrive at the proper flexible spanwise load distribution. This is done by combining the estimated structural stiffness with the estimated rigid load distributions. Some of the final uncertainty resulting from these estimates is removed by wind-tunnel tests of special "loads" models. Such tests usually furnish satisfactory data, even though late in the design, and are useful for checking the original estimated values.

Several serious drawbacks to the present procedures exist, however. First, the timing of the design is usually such that the wind tunnel results could not be made available until after the design had progressed far beyond the economical change point. Second, transonic tunnel time is always at a premium and there are usually several more urgent aerodynamic problems that carry higher priority. Third, the models would either have to possess scaled-down stiffnesses or be built with various estimated deformed shapes; this would not only increase tremendously the cost and time required for such a program, but would reduce the accuracy to the point where the entire value of the tests would be questionable. Several companies, including the writer's, have actually conducted full-scale flight load measurement programs, and the accuracy of even these carefully controlled tests leaves something to be desired.

Another vexing problem is the prediction of loads during rolling pullouts of modern fighter aircraft. These loads could be satisfactorily evaluated for airplanes of a decade ago by using a single degree of freedom equation employing only the yawing inertia, the aerodynamic yawing moments due to rolling velocity and yaw angle, and the damping moment due to yawing velocity. The tremendous fuselage length and density coupled with the extremely low aspect ratio wings of today's fighters yields an inertia distribution which often results in the airplane oscillating quite strongly during a rolling pullout. The single degree of freedom method is completely useless for current types of aircraft.

"The Roll - Yaw - Pitch Coupling Problem," as it is named by experts in the field, is of considerable concern not only to the structures people but also to the aerodynamics and operating people due to the uncomfortable and sometimes uncontrollable aspects of the maneuver. At present, this problem is being attacked by using 5 degrees of freedom and introducing over 20 aerodynamic parameters, many of which cannot be accurately measured. A number of the aerodynamic parameters are

also non-linear and still others are affected considerably by flexibility.

The solution of this problem for the complete range of altitude and speed is indeed a formidable undertaking, and automatic computers are currently being used to obtain the solutions for such problems. At best, these answers are still considered qualitative and subject to verification during flight testing. At least one manufacturer has found it necessary to redesign his production airplanes because of this consideration.

In addition to the major ones such as those discussed above, many minor but none the less necessary and time-consuming load problems now require considerable attention. Some of these are external stores, missile blast, in-flight refueling, dynamic loads during landing, catapulting, and arresting, pressurized compartments (including nacelles in some cases, equipment bays in others), engine stall (seemingly an inescapable culprit), boundary layer control, jet engine noise, boundary layer noise, gun muzzle blast, dynamic loads during rapid mechanism operation, hydraulic "hammer," and thermal loads in hot air ducts. This list, of course, is by no means complete, but should serve to illustrate how the demands of the modern fighter aircraft have taxed the patience and ingenuity of the loads engineer.

Stress Analysis Problems

Internal Loads and Allowable Stresses. The fact that the calculation of internal loads and allowable stresses consumes the major share of the analyst's time is as true today as it was a decade ago. Methods are for the most part the same as those originally used when the first stressed-skin aircraft were designed. One principal difference in internal load calculations is the increased use of the more elaborate redundant methods. The tremendous emphasis on weight, coupled with added structural complexity, has pushed the stress analyst from the "conservative assumption" to the lengthier, more accurate indeterminate analysis. The development of automatic computing machinery has made this situation somewhat more tolerable, but nevertheless, this trend has definitely increased the required man hours.

These methods, of course, have other advantages such as more accurate stiffness estimation and more accurate elastic stress distributions which are needed for fatigue analysis. This type of analysis also offers the advantage of using less experienced engineers to do some of the more difficult internal load estimation problems. Today's booming demand for engineers has resulted in spreading the experienced people so thinly that this is a very real advantage. The use of new types of structures such as multi-web and heavy-skin boxes, integrally-stiffened plates, or sandwiches has provided a steady stream of allowable-stress problems. Some of these have been adequately solved by various research agencies such as the N.A.C.A. Answers to others have been developed by the contractors using both theoretical and experimental techniques.

An example of this is the work done at McDonnell some years ago to establish allowable stresses for multi-web box beams. Early tests of this type of structure disclosed a "corrugated" failure mode. Since no data were available, a simplified theory was developed which visualized the supporting structure as an elastic foundation. Tests were run to establish empirically the elastic foundation characteristics of various supporting structures. This method proved to be quite accurate and has been exten-

sively used during the past seven years to design many light-weight structures.

Structural Efficiency

Considerable time and effort is devoted to establishing structural configurations which will result in the lightest possible weight consistent with geometrical and functional requirements. In the preliminary design stage, this of course requires a broad knowledge of methods of construction and their relative efficiencies as functions of loading intensity. After the type of construction has been selected, much more detail work must be done to optimize suitably the smaller elements. In some cases, general studies are available which make possible rapid optimization of a particular structural type.

In the great majority of cases, however, usable "trend" curves are not available for the peculiar geometry of the individual component. In such cases, the ingenuity of the individual stress analyst must be relied on to produce the optimum configuration. On one particular wing "carry-thru" bulkhead, 100 pounds of weight were saved between the initial concept and the final released design. This was only possible because of diligent work by the stress analyst assigned to this particular component.

Another structural development tool that has been used to eliminate unnecessary weight at McDonnell is the exploitation of an underdesigned structure by means of "stretch testing." Using this approach, the original design is purposely made understrength analytically. Static testing is then carried past the understrength analytical target loads to the final full-strength loads with beef-ups only as required. The final end product thus has all the actually understrength parts beefed up without the weight it would cost to make all the analytically understrength parts full strength. This method can save up to 10% of the airframe structural weight, but it has the disadvantage of delaying the testing, the final design, and the final production of full strength airplanes. This method is fully discussed by Mr. John H. Meyer in Reference (1).

Thermal Demands

The classical thermal problems that are discussed by many learned authorities in the current literature have not yet reached the alarming or "monster" proportions for operational fighter aircraft that they surely will in a few years. At the present time, the temperatures resulting from aerodynamic heating have required some load-factor reductions at the higher Mach numbers, and also have reached the maximum permissible for some plastics and materials. Secondary effects of aerodynamic heating include hot "cooling-air" for engine compartments and equipment bays. This of course results in some additional structural problems.

Some experience is being gained in the design and analysis of structures operating in the 400°F to 800°F range as a result of the fact that it is sometimes necessary to locate the horizontal tail in the engine jet wake. This is required on some supersonic configurations to obtain satisfactory "pitch-up" characteristics. This sort of development testing is considered absolutely vital to successful design of a structural component for this kind of environment.

Other miscellaneous thermal problems are also always present, such as engine compartment design, hot air ducting, boundary layer control installations, heat exchanger installations, etc. In general, though, the major structural design consideration

being given to elevated temperature problems is reduced material properties. Induced thermal stresses are usually checked by a first order, crude method and if found important, they are minimized by suitable design changes.

Fatigue

Today's peacetime economy, together with the more highly stressed modern fighter structures and the higher operational speeds, combine to produce a full-blown fatigue problem. The current dense, integral wing structures seem to exhibit poorer fatigue characteristics than the old style "bits and pieces" variety of structures. Another aspect of these modern structures is that quite often the initial fatigue crack results in immediate catastrophic failure.

On one modern wing design, a catastrophic failure occurred after the application of approximately 700 cycles of limit load in the laboratory. Measurement of stress distribution at the failure station during application of limit load revealed that the peak stress at the skin edge was some 1.7 times the nominal stress several inches forward of the edge, in spite of an extremely gentle planform section change. The theoretical plane stress concentration factor associated with this geometry is only 1.3. Obviously there are more subtle considerations at work here than meet the eye, or than can be predicted by simple theoretical means.

A similar wing with steel straps across the failure region withstood 3700 cycles of limit load, a more than adequate fatigue life. A crack was developed as with the first failure, but then progressed only four inches to a fastener hole. Another 100 cycles were applied after the appearance of the crack until one of the steel straps failed and the crack progressed another 8 inches. This type of failure is much better than the catastrophic.

The example above points out the importance of accurate stress prediction and of careful detail design to avoid section changes and other similar fatigue nuclei. Unfortunately, this is not always possible. Consideration must then be given to ways and means of minimizing these section changes. One such successful method has been the use of parabolic fillets, which were proposed by Grodzinsky for shafts; Reference (2). Fatigue tests at McDonnell on such fillets for plates show the parabolic shape to be conclusively superior to the circular fillet. It is probably also true that the parabolic fillet is superior to the elliptical fillet of equivalent aspect ratio, although comparative tests of this nature have not been made at McDonnell.

Tests such as those mentioned above must be combined with operational statistics provided by the services. These statistics must be suitably modified to account properly for the differences in usage and performance capabilities between the newer airplanes and those for which the statistics were recorded. In order to combine these statistics with the laboratory tests and arrive at service life predictions, estimates must be made of the shape and scatter of the S-N curve and a suitable cumulative damage theory must be selected. The S-N curve shape has up until recently been largely guesswork, but there now exists a wealth of fatigue data on a large number of new P-51 wings (Reference 3). The $\Sigma(n/N)$ cumulative damage theory is currently used at McDonnell, even though it has serious shortcomings, primarily because of its simplicity as well as the fact that so far no other theory has been proved conclusively superior.

In addition to the primary fatigue problem discussed in the preceding paragraphs, vibrational fatigue of external plating has posed serious problems at high operational speeds and with extremely powerful engines. Very limited data are now available to aid in the estimation of either "boundary layer noise" or "jet engine noise," both of which cause this type of cracking. It is hoped that power spectral methods such as that discussed in Reference (4) can be utilized together with empirically determined inputs to arrive ultimately at solutions for these problems.

At the present time, "rule of thumb" methods are being employed to chart a middle of the road course between exorbitantly heavy plating and intolerable cracking. Some contractors have installed extensive test facilities which are devoted to the development of structures to withstand intensive noise. Reference (5) discusses some test results obtained by Boeing from such a facility.

Many additional minor fatigue problems remain to plague the stress analyst in his daily routine. Some of these are found in mechanisms, movable surfaces, control systems, landing gear, and hydraulic systems. In general, the fatigue problem has already grown to alarming proportions, and the years to come will probably prove that fatigue is still in its infancy.

Stiffness Problems

Stiffness Requirements and Prediction. The increased performance of the modern fighter usually means that additional wing and tail stiffness is required to prevent flutter and to provide positive control. On the other hand, the configurations usually selected for these high performance fighters possess thinner surfaces which make the "strength design" stiffness even less than the earlier, lower performance models. These facts mean that the stress analyst must in a number of cases elevate his crude stiffness calculations from the elementary $\frac{TL}{JG}$ methods employed in the past to the more refined, indeterminate methods which more accurately account for discontinuities and section changes. These results are quite often by-products of the redundant analyses required for internal load calculations, but, in some cases, the strength can be satisfactorily provided without the more complicated analysis, whereas an adequate stiffness estimation cannot. Even these time-consuming methods of stiffness prediction are not entirely satisfactory. The problems of joint slippage and the prediction of hysteresis are particularly vexing ones. Hysteresis can be very important to the lateral control problem because it necessitates continual retrim and thus uses up some of the available rolling power. Work is currently in progress at McDonnell to develop methods of predicting these non-linear stiffness characteristics, as well as to develop methods for determining the effects this type of stiffness will have on flutter and control.

In addition to the more or less obvious stiffness requirements, the reduced "strength design" stiffness of the modern configurations has produced several other problem areas. On one model, the landing gear developed an odd phenomenon now referred to as tire shuffle. During braking in certain speed ranges, a violent fore-and-aft oscillation developed. This is not a completely unstable situation, inasmuch as the motion finally reaches a stable amplitude of oscillation. The amplitude, however, becomes quite high. Another problem area lies in the stiffness of the hydraulic power control cylin-

ders and their back-up structure. These cylinders are essentially hydraulic servos and structural deflection usually introduce de-stabilizing feedback. This can result in alarming and dangerous control surface oscillation.

Lateral Control. This problem is not usually thought of as a stress analysis problem, and indeed it is not for rigid airplanes. Unfortunately, at today's speeds and wing thicknesses, the word "rigid" is becoming quite obsolete. When flexibility losses in lateral control approach the 90% mark, then this problem becomes mainly a combination of loads and structural stiffness. The problem is not a complicated theoretical problem until one considers such things as non-linear stiffness, camber effects, and the load distributions which go with these weird shapes.

Considerable effort has been spent trying to do the best possible job on this problem and the score today stands at approximately a ±25% tolerance on the predicted reversal speed for the low aspect ratio fighters that have been studied. Several manufacturers have realized the –25% tolerance in flight testing, and this necessitated some changes to their lateral control systems. Needless to say, this sort of thing is untenable both time-wise and cost-wise. On the other hand, the weight penalties for providing a 25% margin are completely prohibitive.

This problem certainly needs considerable attention throughout the industry. One hope of improving the situation lies in the use of flexible models in the wind tunnel. Some mild success has been achieved using this method, but considerably more development work is still required to perfect this technique. The problem of optimum-stiffness weight distribution to improve lateral control is an interesting and important one. This problem has been extensively studied at McDonnell and the results are reported in Reference (6).

Educational Needs

In order for an undergraduate curriculum to prepare an aeronautical engineer to solve all of the problems mentioned above, it would probably require that at least an additional three or four years be added to the existing four year course. This, even if it were practical, would still probably not be the answer because it is almost an impossible task to ask the universities to keep the curriculum current with respect to the latest industrial techniques. This suggests that the important thing the professional engineer should acquire during his formal education is a very good background of basic fundamentals.

It would be very desirable, for instance, if aeronautical graduates had another semester of differential equations and possibly still another semester of additional engineering mathematics which would include some statistics, some numerical methods, complex variable theory, and other advanced concepts. The thermal problems of the future suggest that perhaps eight to ten hours of "Aeronautical Thermodynamics" would be more useful than the usual three hours of steam tables. An additional course in fluid mechanics taught on a more physical than mathematical concept would be most helpful.

The usual airloads and aerodynamics courses should be supplemented by at least one semester and preferably two of compressible flow theory. At least one and preferably two more semesters of structural fundamentals which discussed indeterminate methods as applied to aircraft, shear lag, aeroelasticity, fatigue, and other such basic struc-

tural subjects would be immensely profitable. Summing up all of the above recommendations reveals that this would require approximately one additional year of study. This might be a very desirable program which would possibly be sufficient for a master's degree. On the other hand, if something must be pared, it is suggested that the amount of work spent in the "technique" courses such as detail design, wind tunnel, physical testing, etc., be reduced.

The above curriculum changes would certainly provide the engineering graduate with a better background with which to embark upon his industrial career. However, the available aeronautical engineering graduate is certainly a capable fellow with quite a good background, and industry's primary complaint is that there are not enough of them to go around. This shortage of engineering graduates has become increasingly acute in the past few years and present trends promise no relief for the future.

Several possible methods for alleviating this problem come to mind. One method is to create and stimulate the interest of our young people in aeronautical engineering as a career at the high school and junior high school levels. Along these lines, professional societies such as the Institute of Aeronautical Sciences and the American Society for Engineering Education can and are using various methods to promote this interest. In St. Louis, for instance, the local I.A.S. Section has produced a number of aviation programs which were shown on the St. Louis educational television station.

The aviation industry should also shoulder a lion's share of this responsibility for creating aeronautical interest. McDonnell Aircraft is currently inviting all local school teachers, from kindergarten to high school levels, to take a tour of the plant facilities, to examine first hand aircraft products, and to become acquainted with the training required to execute properly the various engineering assignments necessary to the completion of a successful airplane design. It is hoped that these teachers will be better informed and thus better able to create and nurture aviation interest in their pupils.

Another fertile field for exploration to reduce the engineering shortage is the training of more technicians. This is discussed by Mr. B. C. Boulton in Reference (7). There exists a large number of engineering tasks now being performed by graduates that could be satisfactorily done by thoroughly trained engineering technicians. Needless to say, a large number of high school graduates who do not now attend college would probably attend such a technician's course if it were readily available. Of course, there are some very good schools now operating along these lines, but it appears that there is still room for a substantial increase in the number of such courses.

Some universities now have separate technical schools under university control and others are considering this possibility. Another approach that the universities could consider would be to offer approximately fifty to sixty-five per cent of the current aeronautical engineering curriculum as an "Aeronautical Engineering Technician's" course. This could include most of the basic mathematics and mechanics together with a considerable number of "specialty" courses in one of several different fields such as Aerodynamics, Structures, or Design.

Such courses would be the full engineering type courses rather than the shortened, less comprehensive courses

usually offered by the technical schools. This curriculum would have to be devoid of such Liberal Arts subjects as English, psychology, and economics, and such engineering courses as electrical engineering, thermodynamics, contracts, and chemistry. A certificate could be issued rather than a B.S. degree to students who successfully completed this technician's course.

This program could be tailored to facilitate the acquisition by the student of a degree at some later date by taking accredited evening courses while employed in an engineering technician's capacity. This feature might require some relaxation by the universities of credit transfer regulations. This would be analogous to the current practice in the nursing profession where a three year curriculum is all that is required for a certificate, but a five-year course is required for a degree.

Another important problem which desperately needs a solution in order to alleviate the engineering shortage is the high migration rate of graduate engineers into other non-technical fields. If ways and means of reducing this engineering manpower loss to one-half of the present rate were found, it would go a long way toward solving the engineering shortage. This problem is of course primarily the responsibility of industry. The key factors are the monetary scales, the lack of professional status, and the lack of genuine interest in aeronautical engineering. Industry must correct the first and partially correct the second factor, professional societies should concentrate on the second and third factors, and the universities should expend a considerable effort on the third factor. The problem is indeed complex and frustrating, one which requires the cooperation of all the groups of our society concerned if we are to achieve a satisfactory solution speedily.

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READING, RUDENESS, AND REDUNDANCY

HIRAM BROWN

Technical Advisor to Plant Manager
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If you have ever attended a convention or any meeting which had a guest speaker, then I have a question to ask you. Have you ever seen an audience imposed upon by a "speaker" who mumbled into the microphone in an almost inaudible manner, or who very methodically "read" his "speech"? Yes, glance about you surreptitiously; that "speaker" may have been you!

Whether you were the listener or the reader, your experience wasn't unique. Even in such learned groups as the ASEE this takes place regularly. It is the unfortunate frequency of such action that leads me to present my views on the three R's of public speaking: reading, rudeness, and redundancy.

Reading

There are a few men who have the ability to *read* their presentations and do an acceptable job of it. Unless you are one of this select few, the effectiveness of what you have to say is greatly reduced by reading. Such handling can be mechanical and often downright monotonous. In reading a paper it is difficult to maintain intimate and spontaneous eye contact with the audience. This link can influence the success or failure of a speaker. By contrast, establishment of actual eye contact with the listeners not only helps to hold their attention but warns a speaker when he is not registering. To continue to talk in the same vein would, in such a case, be a waste of the speaker's time as well as that of the audience—and he should realize it.

Perhaps you sincerely believe that reading your own carefully and well-turned phrases will be more pleasant to hear, or perhaps even will demonstrate your erudition. Actually, it sounds artificial and unnatural. The conversational mode of expression is far different from the written one. Your paper as written may be exactly right to appear in print, but is not your natural way of speaking. Words must be simpler to achieve full impact on a listening audience. So save the compressed, polished version for the JOURNAL—but *not* the oral one!

Rudeness

Also, the audience hopes to see what the speaker really looks like—and not just the top of his head, which shows most when he bends over to read. Unless there are extenuating circumstances, such as last-minute substitution for a cancellation, there is little reason for reading. Usually it is an indication that the speaker has not taken sufficient time to prepare his talk properly.

Ordinarily the speaker is alerted weeks or months ahead of his scheduled participation. Most men are quite willing and anxious to have their name appear on the program, but the presentation can always be dashed off a few days before the scheduled time! The audience has paid the speaker the compliment of coming to hear him. They deserve his best efforts. Anything less is rudeness on his part!

Redundancy

Getting someone to speak (or read) is often easier than getting him to stop. It is unfair to the audience and to other speakers to utilize more than the allotted time. Those who read

are likely to pay little attention to time, because their prime burden and concern is to read all that's in front of them. They lose all track of time.

Believe me, if the speaker must proceed without reading he is not so likely to want to go on at great length —unless he's the natural-born rambler type. In many societies the talks are preprinted anyway and can be condensed for oral-session purposes, mainly to stimulate discussion.

Remedies

"Well," you say, "So you've told us what's wrong. Have you anything constructive to offer?" At the risk of seeming omniscient, I will outline a method of preparing talks which has been quite helpful to me. I'm equally sure that you as individuals can, with a little thought, develop even better methods or, at least, ones equally or more suitable to your personal needs.

First, remember that you have accepted an obligation when you agree to be a speaker. Prepare not only your thoughts but your presentation as soon as you can. Don't let it go until the deadline is upon you. I would suggest as a starter that you sit down and start listing brief notations of all the ideas that occur to you concerning what you'd like to say about the particular subject, including any catch phrases, humorous snatches, or trick wording. Several days later take out these notes and run through them, adding any new ideas or angles that may have occurred to you. By this time you should have a quantity of notes to serve as reminders.

Written Steps

Next, start writing everything that seems pertinent to the notes you have made. Pay no attention to length, grammar, or sequence of ideas. Keep at this until you think you have everything written down. Don't hesitate to scribble notes, corrections, or new ideas in the margins. Many ideas may come as you write, and unless you make note of them immediately they may evaporate. Note, too, any locations where you think slides would be of value.

Now examine what you have written in relation to time. The average speaker will deliver a little over 100 words a minute, say about 2200 words in 20 minutes. This must include comments pertaining to slides, shown three minutes each. All too often the speaker uses his quota of time in the text, and then tries to add additional comments concerning slides or charts. If you have too much written material, therefore, it is wise to cut, combine, or delete the sections that strike you as being weaker ones.

Once the timing is right, the next consideration is the sequence of stating your points. Analyze your approach carefully and then go through your rough draft, placing sequence numbers alongside the various paragraphs. You are now ready to prepare the orderly, well-written draft. This includes checking for correct grammar and spelling.

Oral Preparation

Preparation for oral presentation is next. You might memorize it if you're exceptionally good, but I wouldn't recommend it. This can lead to a monotonous droning recital, lack of spontaneity, and confusion if you are interrupted or if the train of memory is momentarily broken. This is particularly true if you feel nervous before your talk.

Do you think this makes you an exception? Far from it! I have talked with numerous prominent speakers, and most of them admit having stomach butterflies just before they start. Once I asked a speaker if he were ever nervous before a talk.

He calmly replied, "Never!" After I heard him speak I knew why. He was terrible! Believe me, he was so bad he had nothing to worry about.

Try this instead. Get some small 5″ × 3″ ruled index cards. Carefully review your paper and make a few notes on the cards, one note for the main idea of each paragraph. As a rough guide, do not exceed one card of notes per page of speech. Slides can be accentuated by listing numbers ringed in red pencil at the appropriate locations. Slides themselves are good prompters.

There is a very good reason for suggesting such small cards. First of all, they are unobtrusive. Secondly, they are easy to hold in the hands. If you are a little nervous, holding the cards releases some of the nervous energy and answers the question of what to do with your hands. If you wish to keep the cards out of sight as much as possible, they will nest in one hand very well, and you will have the other hand free for gesturing or using a pointer.

Furthermore, since the cards will contain only code words, eye contact with cards can be only a flicker, and you can keep almost continuous visual touch with the audience. Finally, the confidence of knowing that code words are available will help dispel any early nervousness that may exist.

After the cards are prepared, read your written manuscript several times to fix the general presentation in your mind. Then, keeping the written text close by, run through the talk, guided only by the card notes. If you get stuck, look for key words or phrases from the paper and use them as focal points for developing the respective ideas.

After several such dry runs you will find that the cards will be adequate and your speech will have the feeling of spontaneity. Speeches up to 1½ hours in length have been successfully presented in this manner.

This may sound like a great deal of work to you. Actually it isn't too bad provided you've chosen a subject with which you are familiar—and you should certainly not undertake anything else. I'd much rather listen to a well-presented speech with which I disagreed than to a poor one which essentially restated my own ideas.

By the time you have outlined, rough drafted, and final polished a paper it is surprising how much information you will have stored away ready to leap out at glimpse of code words or phrases.

If you have a lot of figures or formulae, on the other hand, put them on slides; don't try to recite them. The audience can examine them visually while you refer to them briefly. If you want to keep a brief talk within time limits, don't waste time with lengthy jokes, and above all don't reminisce unless it's part of your planned presentation.

Next time you are scheduled to speak, why not try some such scheme to avoid being a reader? The audience will enjoy it more, and perhaps you will, too!

HELPING STUDENTS OF SUPERIOR ABILITY

A Program at Purdue University

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If one can judge from the number of articles on the subject which have been published recently, increasing attention is being given to the needs of gifted students in secondary schools and colleges. It has frequently been pointed out in these essays that gifted students warrant special attention because they can develop more rapidly and more fully if they are called upon to use their superior abilities. They are sometimes bored by regular classroom work which is geared to the average or slower student, and if not challenged, they may become content with performance which is satisfactory but far below their capabilities.

The general philosophy of educating gifted individuals and broad recommendations for implementing this philosophy have been adequately covered for the present. See, for example, *Education of the Gifted,* prepared by the Educational Policies Commission of the National Education Association, June 1950, and *Report on Evaluation of Engineering Education,* ASEE, pp. 24–26. Because it is often helpful to know what has actually been done in a few specific instances, however, this article presents a review of the program in operation for superior students in the School of Mechanical Engineering at Purdue University.

A Case Study

The first concerted effort to assist superior students began when the department head appointed one member of his staff to take the responsibility for arranging a program and putting it into effect. The teaching load of the staff member was reduced by twenty per cent to give him time for this assignment. A program of this nature has little chance of success unless the administration regards it seriously enough (a) to assign someone the duty, and (b) to enter it as a justifiable item in the budget.

The second step was that of choosing the students concerned. It was recognized that "What is meant by 'superior ability'?" and "How are students of superior ability identified?" were and are important questions. Nevertheless, if we had tried to reach general agreement on their answers before taking action, we would probably never have got around to helping any student. Consequently, for our purposes, a student of superior ability is defined as one who makes high grades in college, say grades placing him at least in the top fifth of his class. Objections to this definition are recognized, but it is simple, workable, and probably as effective as any in identifying those students who can profit by special attention. The program which has been developed for those students involves accelerated course sequences, other special courses, substitutions in the curriculum, special counselling, a tour of the research laboratories of the department, and opportunities for part-time work on research projects.

Specific Program

Since 1947, two accelerated course sequences have been offered. One is a two-semester sequence covering the

same material and carrying the same total credit as the regular three-semester sequence in heat power and thermodynamics. Both the accelerated courses and the regular courses are scheduled for three meetings per week.

There is also a two-semester accelerated sequence in mechanism, dynamics of machinery, and machine design corresponding to the normal three-semester sequence in these subjects. The acceleration in both cases is accomplished by a reduction in the total number of contact hours and the more effective use of the contact hours which can be made with a selected group.

These accelerated sequences are open to students in approximately the top fifth of their class. At any time during the first semester of an accelerated sequence a student may transfer from the accelerated course to the regular one if either he or his instructors believe that the pace is too fast for him. About one-fifth of the students who enter an accelerated sequence finally make such a transfer. These are sometimes the students with very high grades in all other courses who find that the speed-up or the reduction of contact hours (or both) disrupts their normally effective learning process. Also, a few students who are accustomed to being near the top of their classes are apparently upset rather than stimulated by a group composed entirely of better students.

The chief incentive for students to take an accelerated sequence appears to be that it allows them time later to schedule an extra elective course. Other advantages are those usually associated with a class formed of selected students: classroom discussions are more interesting, less time is needed to cover the same material, and less time must be spent in reviewing the material of prerequisite courses.

On two occasions, students completing the accelerated sequence in heat power and thermodynamics and those completing the regular sequence have taken the same comprehensive examination. The students completing the accelerated sequence made higher average scores both times than did those who had been eligible for the accelerated sequence but had not elected to take it.

A few substitutions for required courses which superior students may make are listed in the University catalog. In addition, each of these students is encouraged to make other course substitutions in accordance with his interests and abilities. Each substitution must be approved, however, by the student's counsellor. Considerable experience has shown that students are often reluctant to deviate from the regular curriculum for fear of "missing something." Surprisingly, students are generally more conservative with regard to curriculum modifications than are faculty members.

A number of special courses are also open only to better students, who may substitute a thesis or individual project for a technical elective course, and in the nontechnical area, may take directed reading courses. Here, the student and the instructor jointly select books for the student to read, and periodically hold conferences to discuss the results. In some courses the student submits written reports, but there are no formal lectures, and the student can read at the pace which suits him best.

It is pointed out to students that they will read perhaps twice as much per credit hour earned in directed reading than they would in a regularly scheduled course. Thus directed reading is not suggested as an "academic bargain" in the sense that more credit is obtained for less work. Such reading courses have now been

conducted in history, in government, and by the Department of English in a broad field of literature.

A few years ago one experimental class of a required American history course was made up entirely of high-ranking students in mechanical engineering. The students reported that the selected group formed a stimulating class, but that using the same textbook and following essentially the same schedule as the regular classes prevented the class from developing fully, even though the instructor was highly capable.

A separate *course* instead of just a separate class was needed, so the History Department assigned one of its best instructors to a course in which there was but one class per semester and restricted enrollment in that class to high-ranking students in mechanical engineering. The course was planned and presented especially for this group. The response of both instructor and students was overwhelmingly favorable. Several students volunteered that the course was stimulating to a degree far beyond that of any other nontechnical course they had taken.

In view of the advantages of a more flexible program under which a student may elect one, two, or many special procedures as he sees fit, no special curriculum for better students has been established. For example, a student strongly interested in mechanics and machine design may elect the accelerated sequence in that area and the regular sequence in heat power and thermodynamics.

Thus more students benefit by a flexible program than by a special curriculum which the student would have to elect as a "package" or not at all. When a special curriculum is established for better students, usually little is done to give the good students who elect the regular curriculum an opportunity to modify their programs. When queried, "What are you doing for gifted students?" faculty members are inclined to point to the special curriculum and forget the unusually capable students who are still in the regular curriculum. Sometimes special curricula are oriented toward research, but many excellent undergraduates are simply not interested in research. (This is a fact which some of us are reluctant to admit.)

Experience has also shown that special curricula are sometimes oriented toward mathematics and "pure" science to such an extent that many students (brilliant and otherwise) who want to be engineers are simply not interested. Another disadvantage of special curricula is that they sometimes require courses to be maintained for very few students. Under a flexible program, each special course is elected by more students than an entire curriculum would be.

The first contact between the special counsellor and high-ranking students is made during their sophomore year. In this "get-acquainted" interview, the counsellor reviews the various special programs or procedures available to superior students and discusses with the student such matters as extracurricular activities and educational objectives. The counsellor enters on a file card for each student any information which may be of value in subsequent counselling.

The second individual contact with all high-ranking students is made early in the junior year. Students are invited to these interviews by a letter which outlines the opportunities for special procedures and curriculum modifications for better students.

The next scheduled contact of the counsellor with high-ranking students is early in the second semester of the junior year, when they are invited to a meeting at which graduate study

opportunities are discussed briefly and a tour is conducted through all the research laboratories in the School of Mechanical Engineering. The students are taken on the tour in small groups, and the staff member in charge of each laboratory is present to describe the work of graduate students in his area.

This tour gives advanced undergraduates a glimpse of research laboratories which many of them would otherwise never see. It gives them a chance to meet and talk with faculty members who are directing graduate students. The meeting and tour are directed toward students in their junior year so that they will know more about graduate study as they select electives and otherwise plan their senior year.

The counsellor of superior students brings together students looking for part-time jobs and faculty members in need of part-time help on research projects. This service gives better students first chance at these jobs and also assures faculty members that the students applying for jobs have good academic records.

These part-time jobs familiarize the students with some phases of graduate research work and give them valuable experience in some research techniques. Working closely with graduate students and faculty members often stimulates an interest in research and graduate study to an extent that courses, lectures, and counselling alone can never do.

Early in the fall semester of each year, high-ranking seniors are invited to a brief meeting at which specific information is presented on selecting an institution for graduate study and on applying for assistantships and fellowships. This meeting is followed by an interview with each student. In addition to scheduled interviews, students may confer with the counsellor at any time.

The counsellor seldom urges a student to undertake graduate study, but instead invites each student to consider graduate study and to make his own decision. The counsellor presents all the facts and data that he can (such as the enrollment figures in the JOURNAL *Yearbook*), but is careful to present both sides of questions. He encourages students to obtain the views of other people before reaching a final decision. It is both unnecessary and unwise to "oversell" graduate study.

In the same way, throughout his entire undergraduate program, a student must *volunteer* or *apply* for special procedures which are open to him by virtue of his superior ability. It is made clear that the initiative rests with *him*, and that he can profit by these special opportunities only if he takes action on them himself.

Results

It is difficult to evaluate quantitatively the results of a flexible program such as this one. Some results which can be expressed in terms of numbers of students are: (1) more students are making substitutions in the regular curricula to capitalize on their interests and abilities, (2) more students are taking the challenging elective courses in both technical and nontechnical fields, and (3) several superior men are already working with graduate students and faculty members on research projects.

The most striking result, in general, is that the number of graduates entering immediately upon graduate study *increased by a factor of three* in *two years*. Even in view of nationwide trends toward graduate study and changes in the military service picture, most of this increase can be accounted for as a result of the program just described for helping superior students to get more from their undergraduate education.

ON TEACHING THERMOPHYSICS

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It occurred to me one day that I might attribute my interest in thermophysics to a tradition established at Yale by Josiah Willard Gibbs. Then I remembered that as a graduate student there I had never had a course in this subject. As a matter of fact, when Walter Nernst visited the Sloane Physics Laboratory he was chagrined to find no memorial to Gibbs. Accordingly he himself supplied the plaque now seen in this laboratory. Recently I was discussing the teaching of thermodynamics with Newman A. Hall of the Mechanical Engineering Department. He remarked that as a newcomer at Yale he had been impressed with the lack of any advanced graduate course at present dealing primarily with thermodynamics. My social justification for presenting these comments, therefore, is greatly wanting; all that I can offer is my continuing personal interest in thermophysics.

For some time I have wondered about the thermodynamics courses being offered in physics at both the undergraduate and graduate levels. Accordingly, I recently looked over the catalogues of thirty-one schools, all of which grant more than four Ph.D.'s per year in physics. Among the undergraduate courses specifically listed, nineteen institutions offer thermodynamics or heat or both; six offer thermodynamics plus kinetic theory and statistical mechanics; five offer only kinetic theory and statistical mechanics; four institutions offer no undergraduate courses in the whole field.

Most of these courses are three semester hours, although a few are two semester hours only, and an occasional one is more than three. Evidently the thermodynamic viewpoint rather than the statistical one is predominant at the undergraduate level in these particular institutions. Whether or not this practice is desirable is a legitimate question.

As for graduate offerings that are distinct and not merely a portion of an omnibus course in theoretical physics, twelve institutions offer courses in thermodynamics *per se;* sixteen offer courses in statistical mechanics, or in statistical mechanics including kinetic theory; seven offer courses in statistical mechanics, sometimes including kinetic theory or thermodynamics; two institutions have no such graduate work at all. These courses usually run for three semester hours, although there are a few that are for four to six semester hours.

In addition, three courses on low-temperature physics are listed. It is evident that the statistical viewpoint is predominant in graduate courses. After teaching such a course several times I found myself including thermodynamics as a deductive part of rational statistical physics (1). Again, one may reasonably ask whether or not this point of view is desirable.

Objectives

This cursory review raises serious questions as to just what the objectives of thermodynamics courses in physics are and just what they should be. Let us begin our consideration of this matter by looking at various views of thermodynamics itself.

Arnold Sommerfeld (2) confesses, "In my original view I used to devote more time to statistical mechanics as compared with classical thermodynamics because I was personally drawn more to the former on account of its relation to quantum theory." He notes, however, apparently as an afterthought, "Thermodynamics did originate from the needs of steam-engine builders" (cf. the mathematical analysis of N. L. Sadi Carnot, 1824).

The final report of the ASEE–NSF Conference on Thermodynamics (3) began with these words, "Thermodynamics is an engineering science." Max Born (4) cites thermodynamics as involving "new and strange concepts, obviously borrowed from engineering." Referring to the somewhat arbitrary use of *ad hoc* cycles for fictitious engines, he remarks, "Even as a student, I thought they differed too much from the ordinary methods of physics." Later he insists, "This state of affairs seems to be the one of unhealthy conservatism."

It is not altogether surprising, therefore, that in John Slater's "Modern Physics" (1955) the word thermodynamics is not even mentioned. As he notes, "Twentieth century physics is essentially atomic physics." We find Erwin Schrödinger (5) asserting, "The laws of physics, as we know them, are statistical laws." And Edward A. Guggenheim (6) insists, "It is possible to obtain a deeper insight into fundamental principles from a statistical point of view."

On the other hand, Percy W. Bridgman (7) cautions that it is "strange that we are more satisfied by explanations of the macroscopic by the microscopic using macroscopic laws." An experimentalist might well question the dictum (8) that thermodynamics "has its foundation in the statistical mechanics of atoms" (particularly in view of the uncertain foundations of probability).

Perhaps Paul S. Epstein (9) offers the best compromise. Recognizing that modern thermodynamics usually involves a cumbersome amount of material, owing to the usefulness of statistical theory for chemical applications, he therefore urges that "a course in phenomenological thermodynamics has again a useful place in the curriculum." From these typical quotations it is evident that the need to clarify the objectives of all thermodynamics courses, both graduate and undergraduate, is a vital issue and not an academic footnote.

I myself would support the thesis that physicists should teach thermodynamics as thermodynamics, a distinct discipline valuable for its own sake. (I would not argue as to whether it should be given to seniors or first-year graduate students.) As Gilbert N. Lewis (10) has reminded us, thermodynamics is still "a monument to the power of the human mind."

In connection with Ludwig E. Boltzmann's derivation (1884) of Joseph Stefan's formula for the emission of radiant energy, Hendrick A. Lorentz (11) once remarked that it is "a veritable pearl of theoretical physics." (Boltzmann extended the concepts of pressure and of temperature to cavity radiation.) Born, too, points to concepts like entropy and absolute temperature as a "wonderful achievement." This glorious theoretical heritage is not the only basis for separate treatment; there are two additional important advantages.

Reasons

In the first place, thermodynamics is an interesting example of the scientific method, in that its theoretical structure is based upon a few axioms well established from experience (12). From these few principles one is able to derive formally many relations among observables (13). It is noteworthy that the original foundations of thermodynamics have withstood the quantum revolution, whereas mechanics has not been so fortunate. Recently, Nathaniel Frank, of the MIT Physics Department, and I were discussing the undergraduate mechanics course given at the Massachusetts Institute of Technology. He advocated the teaching of mechanics for its exemplification of the scientific method—an instance *par excellence* in the field of physics. I noted, "Except for thermodynamics!" He agreed. Of course, in any axiomatic approach one must be ever alert to present the material as incomplete and growing, i.e., from a research point of view.

Secondly, it is well to bear in mind that thermodynamics still affords an adequate and accurate description of many physical occurences, even if not a full explanation of all. Fluctuation phenomena, which represent an important exception, do not invalidate the rest of the picture. The very fact that thermodynamics contains no simplifying assumptions, like those occurring in statistical mechanics, is actually an advantage.

What is more, in a field like fluid dynamics (14, 15) when one combines thermodynamics and mechanics, as in compressible flows (aerothermodynamics), one obtains a more powerful tool to investigate phenomena than the laws of motion by themselves. It is not just the independent disciplines of mechanics and of heat that are important here, but rather their interrelations. The unique domain of statistical thermodynamics might be kept for a second course; it would include entropy changes for highly dispersed systems, for mixtures of very similar substances, and for very cold systems.

In short, I would teach introductory thermodynamics as thermodynamics—a branch of physics. In so doing, of course, I would emphasize the rigorous treatment of its fundamental concepts. Statistical associations, as well as engineering and chemical illustrations (wet steam and real gases), would be included, but thermodynamics would be taught primarly as physics. This point of view (16) should not preclude a chemist from teaching chemical thermodynamics where the stress would be on chemical applications, or an engineer from giving engineering thermodynamics with an emphasis on engineering problems.

Guggenheim begins his book *Thermodynamics* (5) with the statement, "The term thermodynamics is a misleading word; the fact is that the word suggests non-equilibrium as the result of the use of the word dynamic." He recommends the term "thermophysics." I, too, would prefer to use this word, although I am quite conscious of the fact that such a change may not be practicable at this advanced state of usage. This term is logically preferable in that heat is a factor that affects phenomena in all branches of physics.

Most physical phenomena are dependent upon temperature; for example, the frequency of the vibrations of a string, the compressibility of a gas, the capacitance of a condenser, the mutual inductance of a transformer. Thermophysics, moreover, should comprise also phenomena in which temperature plays a primary role, such as thermoelectric, paramagnetic, and dielectric properties; superconducting and superfluid materials, and

fluid, with charged particles (electrons and ions).

From the standpoint of so-called modern physics, one should certainly include solids and liquids as well as gases, regardless of the theoretician's desire to utilize the simplest model of a thermodynamic system, *viz.*, a homogeneous fluid. It is not only that thermal effects are significant; the mechanical description of such phenomena is actually inadequate.

If one neglects temperature, as is customary, one does obtain only five equations (three for motion, one for continuity, and a stress-strain relationship like that between pressure and density). Five variables (pressure, density and the three velocity components) are then sufficient to describe the mechanical aspects of phenomena. Temperature, however, must be added as a sixth variable; a sixth equation with an appropriate boundary condition is now necessary to obtain a complete solution.

Three Aspects

Thermodynamics, accordingly, should be taught as a discipline embracing many branches of physics and not just heat. Furthermore, I would stress three aspects (17): (1) an operational point of view with respect to the world of physical phenomena, (2) the use of mathematics with respect to the world of physical concepts, and (3) philosophical interpretation with respect to the world of physical theory.

In considering the need for an operational point of view, to be sure, I would emphasize at the start that thermodynamics is obviously limited theoretically by the atomic structure of matter and practically by the scale of instruments available for investigation. The latter handicap, however, should not bother us, inasmuch as all physical data are necessarily smoothed or "fudged," thus permitting a causal description. In all these emphases we note the necessary anthropomorphic character of science.

In preparing this article, I wrote to some book companies to ascertain the present "popular" college text books in general physics courses. I subsequently read the portions of twenty-nine texts (all published since 1940) dealing primarily with the subject matter of heat, thermodynamics, and kinetic theory (about 23% of the total material).

In each instance I specifically made a point of also looking up a concept in the index in order to insure my reading what the author himself regarded as pertinent information. (This method, of course, is dependent upon a good index.) In general, I found considerable confusion with respect to fundamental concepts in thermodynamics, a confusion that could be greatly decreased by greater emphasis on an operational point of view. I shall illustrate the reason for this conclusion by a few examples.

Temperature

Let us consider first of all the concept of temperature. Among the texts reviewed, two did not bother defining temperature at all, eleven were content with referring to it quite anthropomorphically as hotness or coldness, and nine regarded it as some unspecified factor that determines the direction of heat flow. There was an occasional mention of temperature being average (not synonymous with random!) kinetic energy or intensity of heat or thermal level. To me an unusual definition of temperature was "that which is measured by a thermometer." (At least this definition is operational.)

Despite the fact that every author apparently regards temperature as a fundamental concept, he is usually

satisfied to introduce it in a hazy fashion and to permit it to stay that way throughout the book. In an older text (18) there is actually an expression that "A satisfactory definition of temperature is at present impossible; the definitions which have been proposed either contain vague claims which render their use exceedingly unscientific, or else they define a state, of which the possible knowledge of certain assumptions which are really forced upon us by phenomena, are connected with the very conditions which we seek to define."

Rightly or wrongly, the casual reader certainly gets the impression that any old scale of temperature will do—even that of a perfect gas that is freely admitted not to exist. I do not mean to infer that difficult concepts need not be presented at the student's level of psychological and intellectual maturity. I believe, however, that there is a threshold level of intellectual attitude below which one is not really discussing physics as a science.

Temperature must be logically based upon the concept of thermal equilibrium. All thermodynamics (19), indeed, is necessarily concerned with thermal equilibrium because it is requisite for a definition of temperature (cf. R. H. Fowler's axiom, the so-called "zero" law of thermodynamics). We start with the fact that if a body A is in thermal equilibrium with another body B, and body B, in turn, is in thermal equilibrium with a third body C, then A must necessarily be in thermal equilibrium with C.

It is appropriate, therefore, to begin with a room in thermal equilibrium. The so-called physical "state" of a body in thermal equilibrium may then be specified in terms of a number of independent physical properties. These variables are found to be related in some fashion, dependent upon another variable, the so-called temperature which changes with a change in thermal equilibrium. For example, in the case of an ideal gas with pressure p and volume V, the product pV remains constant as long as the temperature is unchanged, or as long as the thermal equilibrium remains the same. A function like pV is experientially determined from isothermal behavior of the gas.

If the temperature changes, however, $pV = RT$ (the thermal equation of state). This procedure involving thermal equilibrium deceives no one; it does not directly give a physical meaning of temperature; it merely defines equality of temperature, or an arbitrary function of temperature. It would seem desirable even in a beginning course to discuss qualitatively the meaning of temperature for a nonhomogeneous body, for a strong radiation field, for a change in the physical system, as say from an ortho state to a para state in hydrogen, or for steady states like heat conduction.

In the measurement of temperature, it is important to keep in mind that the proper scale of an instrument depends both upon the size of the object being measured and upon the time during which physical changes take place. One must be careful also of particular qualifications, e.g., a flat thermometer (like a pressure gauge) will read differently depending on whether it points parallel or perpendicular to a stream. A thermometer accordingly should always move with a stream.

In a beginning course, inasmuch as mechanical work always involves relative motion, one might note that there is a factor here, too, which is usually neglected. The climax of any discussion of temperature should deal with the concepts of absolute temperature and of absolute zero. Sommerfeld (2) observed that the whole structure of the science of thermodynamics

would collapse without the existence of a fixed but unobtainable lower limit of temperature.

First Law

Let us now consider operationally the first law of thermodynamics, which is concerned with "quantity of heat," associated usually with temperature change. Among the elementary texts reviewed, three fail to give any definition at all of "quantity of heat"; nine indicate that it depends somehow upon molecular motion (three of these specify the kinetic energy of molecules); nineteen are content with describing quantity of heat as some form of energy. An unusual definition states that quantity of heat is "the most low-down form of energy."

More tantalizing are remarks like "work is a form of heat," and "energy is heat, or anything that can be converted into heat." Such false deductions, I suppose, are understandable if one wrongly associates the premise that heat is a form of energy with the premise that energy is capacity to do work. Throughout much of the discussion of heat in these elementary text books, there is latent the idea that heat is a material substance. The caloric concept (20) today persists in the colloquial expressions of teachers (cf. the "flow of heat").

Real imagination, I confess, is required here to visualize that heat which has been introduced into a system is not retained in that system as heat. In this connection, I am reminded of a statement attributed to Schrödinger with respect to certain particles that escape from atomic nuclei. "How can these particles come out if they are not inside?" was the common query. Schrödinger observed that just because a person goes into a bathroom all dressed, he does not necessarily remain dressed there while he is taking a bath.

Systems

Thermodynamics is always definitely associated with walls or enclosures, be they adiabatic, diathermous, or semi-permeable, so that one must initially specify a system and its boundaries. In acoustics, for example, the vibrations may be so rapid that there is no time for heat to be transferred out of a given region, and the phenomenon can be considered as virtually adiabatic.

The crux of the matter in the first law of thermodynamics, then, is the behavior of a given system as the result of interactions (21) with other systems in the form of work and of heat. One might begin by noting that thermal convection is not heat interaction in a strictly thermodynamic sense, whereas thermal conduction and radiation are. Bridgman has emphasized that it is necessary to consider the general condition for which heat and work can be defined. In the case of small-scale turbulence, for instance, do we have an exhibition of mechanical energy, or of heat, or of both? Radiation, too, poses an interesting question of the same kind.

Textual Treatment

Among the texts considered, eight do not even mention the word thermodynamics; two regard the first law as an expression of energy change independent of path; five associate it with the mechanical equivalent of heat; and nine view it as the conservation of energy (three as a general expression of that law, and four as a specific statement with respect to heat). A somewhat strange formulation is this one: "The first law of thermodynamics is frequently referred to as the mechanical equivalent of heat." If one uses the individual terms in

their broad meanings, this statement makes sense, but it may be misleading to a person concerned with science as precise terminology.

Actually, the first law of thermodynamics involves a new physical concept, namely, internal energy. In general, one should speak strictly of an energy function, inasmuch as changes only can be measured. Unless one is very careful, however, the first law may become mere tautology. For example, Alan H. Wilson (22) states, "The first law of thermodynamics is not very illuminating since it merely shows that the internal energy is a function of the state and provides a definition of heat." Born (4), Fermi (23) and Guggenheim (6) all use the first law merely to define quantity of heat. I personally believe that it is preferable to regard the law as describing an experimental relation. Starting with the concept of a physical state which is described by certain independent variables, including a physical quantity that we will designate internal energy, we observe that, regardless of the input and output both of work and of quantity of heat, the change in internal energy of a body remains the same when the physical state changes, independent of the path of that change.

If one were to come across a possible new form of energy, one would have to check the new energy functions to ascertatin whether the new form would satisfy similar conditions. This would not be just an arbitrary correction to balance an equation (24).

Conservation of energy, however, is actually broader than the first law of thermodynamics. There is great danger is using technical words in so careless a fashion that they may lose their precise meanings. For example, to say that mass is the same as energy is not quite correct, inasmuch as physically they do not have even the same dimensions.

Second Law

Let us turn to the second law of thermodynamics. Max Planck (25) once said, "The problem of formulating the second law of thermodynamics has occupied physicists for decades." Unlike the first law, there have been many attempts to disprove it. On the other hand, a proof which is based upon an idealized concept, like that of a perfect gas, is far from being convincing.

Here, too, one meets a new concept, namely entropy. Four of the above elementary texts give a formula for entropy: namely, the ratio of change of quantity of heat to absolute temperature. Only two of these texts, however, specify the condition of reversibility (preferably the idea of a quasi-static process), without which the formula does not hold. Twenty-four texts make no mention of entropy at all. In his paper (3) on "Thermodynamics for All Engineering Sciences," George A. Hawkins claims that "The nature of entropy is not like that of temperature or pressure. It is a subjective concept rather than objective."

On the contrary, Schrödinger (5) stresses: "What is entropy? Let me first emphasize that it is not a hazy concept or idea, but a measurable, physical quantity just like the length of a rod." We recall that in the 19th century Gustav Kirchhoff actually wished to restrict the concept of entropy to so-called reversible processes (actually a succession of equilibrium states). It was Planck (26) himself, however, who emphasized in his doctoral thesis the general validity of the concept and its applicability to radiation—an investigation which was to lead in 1900 to his formulation of the quantum theory.

The point here is that only the initial and final stages, say of an expanding gas, are to be regarded as causally related by the mathematical description, not the intermediate states. The concept of macroscopic reversibility and irreversibility, therefore, is concerned only with the initial and final states, not necessarily with the transformation process itself. It is evident, then, that one must treat entropy operationally. As Guggenheim (6) has emphasized, the early introduction of the so-called third law of thermodynamics was not essentially a new principle but merely a means of measuring entropy, and thereby of rendering that concept more useful.

The Theory

Turning now to the second law itself, we find that there are usually two types of formulations: one going back to the original statement of 1850 by Rudolph Clausius in terms of heat transfer (cf. his introduction of the concept of entropy), the other to the independent one by William Thomson (Lord Kelvin) a year later with respect to heat transformation (cf. his introduction of the concept of absolute temperature). It is important that a student understand in detail the equivalence (27) of these two statements.

Five of the reviewed texts attempt to formulate the second law in terms of the transformation of heat into work. One states categorically that a complete transformation is impossible; two stipulate that it is impossible only if there are no associated changes; the other two specify that it is impossible only for cooling alone.

Twelve of the texts, however, prefer to regard the second law as concerned with the impossibility of heat transfer from a body at a given temperature to one at a higher temperature. One of them is quite content to say with finality that such a transfer is always impossible, another states that a self-acting machine cannot accomplish it, three specify that it cannot be done spontaneously, three others insist that it is impossible even for a cyclic process, and four restrict the impossibility to the case when no work is done.

More than one hundred years have elapsed since the first formulation of the second law of thermodynamics. It is truly surprising that the average textbook does not contain as good statements of this law as those made originally by Clausius and by Thomson, who carefully noted the restrictive conditions.

Examples are always helpful in clarifying concepts. Let us now consider a few; first, a transformation involving heat and work. Heat an ideal gas at a constant temperature and allow it to do work under expansion. While there is no change in internal energy, the energy available at the end of the expansion is less than at the beginning: there has been a change of entropy. This fact is recognized immediately if the law is stated, as it should be, in terms of cyclical processes.

Or, to take another case, let us consider the transfer of energy from a portion of a gas at a low temperature to another portion at a higher temperature. Suppose the gas chamber is divided into two compartments, separated by a movable piston. Let the gas on one side be at high pressure and low temperature, while that on the other side is at a lower pressure and a higher temperature. The piston will then be forced from the high-pressure side to the low-pressure side; the high-pressure gas will become compressed and hotter. Effectively, internal energy will have been transferred from a cool gas to a hot gas. Here again we note that the process has not been cyclical so that there is

no violation of the second law of thermodynamics.

Finally, we look at a recent incident. A reviewer of Leon Brillouin's book (28) *Science and Information Theory* objects to his comment that electrical energy is a higher form of energy than chemical energy. The reviewer (29) argues, "Neither does he explain how, if electrical energy and chemical energy are of different grades, we can have a reversible electrochemical reaction as in a storage battery." Thomson himself committed the same error years ago with respect to a Daniell cell, which shows an apparently reversible change of electrical and chemical energy. The complete analysis (30) is given in the Helmholtz equation, which includes the possibility of thermal energy being produced from internal energy. (The same correction arises in the Joule free expansion of a real gas.)

One has to be careful also that popular statements about the second law of thermodynamics may not become confusing in their over-simplification. Take, for example, Kelvin's remark (1854) that there is a tendency towards the dissipation of mechanical energy. What happens, however, if the initial and final states have the same energy, as in the case of self-diffusion or in the dilution of a dilute solution?

Or, consider Maxwell's emphasis (1860) upon increasing disorder. How does one then account for an undercooled liquid crystallizing at a higher temperature and having an increase in entropy at the same time? Albert Einstein, indeed, has emphasized that the second law is broader than the mere observation that heat will not go spontaneously from a body at a low temperature to one at a higher temperature.

Whenever there is a transfer of heat, even from a body at a high temperature to one at a lower temperature, the process is inherently irreversible. There is always an indelible imprint upon the physical universe; the final state of the system cannot be obtained reversibly from the initial state. In this instance the energy available for work at the final low temperature is actually less than that available at the initial high temperature.

Confusion as to the relationship of entropy and availability of energy can apparently occur even among the experts, as the following footnote in Lord Rayleigh's edition of Clerk Maxwell's classic (31) shows: "In former editions af this book the meaning of the term entropy, as introduced by Clausius, was erroneously stated to be that part of the energy which cannot be converted into work. The book then proceeds to use the term as equivalent to the available energy, thus introducing great confusion into the language of thermodynamics." One evidently needs a rigorous presentation of the second law of thermodynamics.

An operational point of view will certainly help the achievement of this objective. Terms like Clausius' "energy of the universe" and "entropy of the universe" must be operationally differentiated from laboratory usage of the words energy and entropy. Edmund Whittaker's principles (32) of impotence, too, would become less mysterious, if we could express our concepts positively and concretely.

Mathematics and Physics

Let us now consider my second emphasis, which is concerned with the use of mathematics with respect to the world of physical concepts. Thermodynamics is so well developed that it truly has become a mathematical science. There are, however, two distinctive mathematical points of view,

practical mathematics for doing and theoretical mathematics for viewing. With respect to the former, Bridgman (7) has observed that thermodynamics is "the most difficult branch of physics to teach"—possibly because of the different mathematical formalism that is used here as compared with that in other branches of introductory physics.

It is just this mathematical difference, I believe, which makes the teaching of thermodynamics a broadening influence in the education of a physicist. Here, for the first time, one becomes acquainted with functions of different kinds of variables, inasmuch as the state of a system depends upon more than one physical quantity. For example, internal energy can conveniently be expressed as a function of volume and of temperature (the so-called caloric equation of state), or as a function of entropy and of volume.

Moreover, functions like that of internal energy are not point functions, like kinetic energy, which is unique with respect to the velocities at a point. The state, too, may often be given by an implicit function; for example, $F(p,V,T) = 0$ so that many types of partial derivatives are necessarily involved.

Now there are ten basic thermodynamic quantities with 720 important first derivatives, resulting in $(10)^{10}$ relations involving four derivatives (cf. Maxwell's relations in 1883). A useful function in this connection is the Jacobian, which relates the derivatives of different independent variables. What is evident, but not often stressed in a begining thermodynamics course, is that some kind of classification system is requisite. Bridgman, for example, has shown that one need be concerned only with a minimum of forty-five relationships.

It was Clausius who originally noted the desirability of expressing thermodynamic laws in terms of quantities independent of the path of change. The study of thermodynamics accordingly is facilitated by the use of exact differentials—in the mathematical sense, rather than in the physical usage of something very small. One sometimes forgets that even entropy is first of all a function, at times an elementary function. For simple cases it may naturally appear in relations involving the first law.

For example, the reciprocal of the absolute temperature becomes merely an integrating factor for a reversible change in quantity of heat under adiabatic conditions. One should be introduced also to Gibbs's thermodynamic potentials (33) which afford a more convenient and less arbitrary method than do intuitive cycles.

The derivatives of such functions enable one to determine readily physical quantities. The choice of the functions themselves depends upon whether or not they are maximized and minimized under specific physical conditions. One learns here how important it is physically to choose particular variables as the independent ones.

In a beginning thermodynamics course, it would not be appropriate to stress theoretical aspects of the mathematics involved. I do believe, however, that one should call the student's attention to more abstract questions like the fundamental properties of perfect differentials (for example, the geometrical properties of certain differential equations and their solutions). Born (34) points out that "Pfaffian equations are the mathematical expressions of elementary thermodynamic experiences."

Constantin Carathéodory (35, 36) (1909, 1925) has shown that the most satisfactory formulation is given when

the internal energy is expressed as a function of entropy and of volume. Starting with the observation of certain physically impossible processes, he is thus able to arrive at a mathematical expression of the second law from a postulated principle of inaccessible states, i.e., the existence of adiabatically inaccessible states in any vicinity of a given state. He simultaneously proves the existence of functions behaving like entropy and like temperature.

The intellectual beauty of his method is that the whole of thermodynamics can be derived from a very few axioms—a scientific achievement not to be discounted. From a pedagogical viewpoint, of course, the Carnot-Clausius use of cycles is much more instructive and thoughtful in a beginning course in thermodynamics.

Philosophy

Finally, let us consider briefly my third emphasis on the need for a philosophical approach. Born (37) has said "Physics free from metaphysical hypothesis is impossible. . . . Science is not only the basis of technology, but also the material for a sound philosophy." In the case of the second law of thermodynamics, one has a unique opportunity to discuss philosophical (37) questions. In view of the fact that every one else will discuss the philosophical aspects of science, with or without physical comprehension, it seems mandatory that the physicist himself make clear the scientific limitations, as well as possible philosophical interpretations, of this law. In the very year (1860) that Clerk Maxwell first suggested the possible relation of the second law of thermodynamics to increasing disorder, Herbert Spencer published his *First Principles,* clarifying the then new principle of evolution, but completely ignoring the better validated second law of thermodynamics.

It is interesting to note historically the many theological interpretations (38) that have been given to the second law, beginning with Kelvin, who was concerned in 1852 with the beginning and the ending of the universe. The very thought that there may have been a beginning suggests that there may have been a creation. On the other hand, William R. Inge remarked in 1933, "Modernist philosophy is wrecked on the second law of thermodynamics."

Even in 1957, Elton Trueblood (39) notes in his interesting book *The Philosophy of Religion* that "The second law of thermodynamics thus points to theism as an explanation of the world—science, instead of undermining belief in God, becomes the first witness." Pope Leo XII (40) has expressed a similar view. Inasmuch as the second law represents a principle of history, there are bound to be diverse metaphysical interpretations (41) if it is considered together with other cultural aspects.

Thinking now of the more general philosophical interpretations, one finds Henri Bergson (42) noting that the second law is "the most metaphysical of the laws of nature." More recently Arthur S. Eddington (43) has regarded the second law "as having the supreme position among the laws of nature." He bases his conclusion upon the fact the second law deals with time, i.e., subjective time (according to his view).

Under any circumstances the second law has become a battleground between materialism and idealism. (The latter view is exemplified best by James H. Jeans (44).) Materialism and naturalism, on the contrary, have also found comfort in the view that chaos can certainly not be regarded as a proof of design. Thus we

note that the same law is used to support both sides of the case.

What is evidently needed here, as in all the rest of physics, is a clear understanding of the nature of a physical law and of its limitations. For example, take the universe *per se*. Is it bounded or is it infinite? If bounded, is the boundary moving? If the boundary is moving, is there an energy leak? Evidently broad changes in thermodynamics may be required to accommodate relativistic and cosomological theories (45).

The very fact of life itself presents additional complexities. In 1946, Bridgman asked how one can calculate the entropy of a living substance, inasmuch as a reversible process is necessary to make possible any physical measurement of entropy, and there is obviously no known reversibility between the states of life and of death. As Brillouin (29) has suggested, the study of unstable equilibrium or negative catalysis may contain a clue. In this connection, we note that there is a possibility of a life principle with or without a physical-chemical basis.

Finally, consider the general problem of intelligence. Norbert Wiener (46) has emphasized that any "amount of information is the negative of the quantity usually defined as entropy in similar situations." What is the difference in entropy between a comic book and a cosmic book? Is it possible to arrive at a generalized concept of entropy that will be applicable to both? One can obviously go on at great length discussing philosophical interpretations of thermodynamics in general, and of the second law of thermodynamics in particular.

Conclusions

Let these few remarks suffice to call your attention to certain emphases in teaching of thermodynamics, which, I believe, are quite essential from the standpoint of a physics student: first, an operational view, because it will lead to clearer physical concepts; second, a mathematical point of view, because it will result in a clearer understanding of functional relations; and finally, a philosophical point of view, because it will outline limitations of the applicability of these basic physical laws to life (5, 47, 48), the life that we all live. I would recommend therefore that we consider how to improve the teaching of thermophysics at all levels of instruction from these and various other applicable points of view.

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APTITUDES AND ATTITUDES

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With the forming of the Society for the Promotion of Engineering Education in 1893, the first concerted effort was made to study and evaluate engineering curricula on a national scale. The many reports that have been made through the years have resulted in tremendous forward strides in both the art and science of curricula development. The highest of these several plateaus was reached in June 1955 with the presentation of the "Report on Evaluation of Engineering Education" by Dean L. E. Grinter and his committee. The work of the "Grinter Committee" has been very impressive and very effective, yet for some people one important area has not been sufficiently emphasized. This might be called the "human relations" or "attitudes" aspect.

One point of the summary of the previously mentioned report states in part that "Positive steps (should be taken) to insure maintenance of faculties with the intellectual capacity as well as the professional and scholarly attainments necessary to implement the preceding recommendations (of the report)." There is no quarrel with this recommendation except that it does not go far enough. Together with curricula changes and development of professionally qualified faculties goes the necessity of a program of self-development of those faculties in terms of their attitudes and their ability to get along with other people. "Getting along" is important, as evidenced by the fact that far more staff members, both in industry and in education, fail to progress satisfactorily because of inadequacies in this area than for all other inadequacies combined, including lack of technical abilities.

Assumptions

To eliminate some of the variables, we can assume that the professional competence of the instructor has been thoroughly checked and is above reproach; we can further assume that the curriculum has been established at the best level presently known. Just as important as professional competence and curricular planning, indeed, in some ways more important, are the attitudes the individual instructor brings to and displays through his teaching. Sometimes these attitudes are expressed; sometimes implied; and often conveyed completely by actions of the individual. In any event, all instructors and professors need to stop for intensive introspection of their own attitude levels.

For convenience only, not to imply mutual exclusiveness, we can divide attitudes into three major groupings:

1. Attitudes as an engineer
2. Attitudes as a teacher
3. Attitudes as an individual

Obviously a complete discussion of every phase of all of these attitudes is impossible within the limitations imposed. A few points will be considered under each area with the idea that individual thought and consideration will add extensively to the list, and with the hope that some good may come from even this small amount of self-examination, evaluation, and introspection.

Responsibility As An Engineer

Perhaps the first attitude that should be developed as an engineer is the acceptance of engineering as a profession; and, as a corollary, the development of a truly professional attitude. Much is implied in the preceding statement, including a discussion of the many definitions and implications of the term "profession." This is neither the time nor place to explore completely all of the possibilities. Suffice it to say that professionalism indicates individuality of action, reward, and responsibility. It indicates the development and practice of a code of ethics which is beyond criticism of those either in or out of the profession. Perhaps the best approach to this ideal so far is the preamble to the Canon of Ethics of the National Society of Professional Engineers:

"Honesty, justice and courtesy form a moral philosophy which, associated with mutual interest among men, constitutes the foundation of ethics. The engineer should recognize such a standard, not in passive observance, but as a set of dynamic principles guiding his conduct and way of life. It is his duty to practice his profession according to these Canons of Ethics.

As the keystone of professional conduct is integrity, the engineer will discharge his duties with fidelity to the public, his employers and clients, and with fairness and impartiality to all. It is his duty to interest himself in public welfare, and to be ready to apply his special knowledge for the benefit of mankind. He should uphold the honor and dignity of his profession and avoid association with any enterprise of questionable character. In his dealings with fellow engineers he should be fair and tolerant."

Only one other point needs consideration in the development of a professional attitude: the necessity of continuing education not only through work on any advanced degrees but throughout a man's entire professional career. True, there are many rewards to being a professional, but each of those rewards is closely coupled with one or more responsibilities. When we accept one we must at the same time accept the other. They are inseparable.

Responsibility As a Teacher

Attitudes as a teacher can be subdivided into three groups:

1. Toward teaching as a career
2. Toward a particular college or university
3. Toward particular courses

Much thought and discussion has gone into the question of interesting more people in teaching engineering. As a result almost everyone has his own pet theories as to what should be done. Perhaps the most popular theory is based on raising professors' salaries. No one in the teaching field could conceivably object to an increase in income, yet this increase, of and by itself, will not expand the numbers of qualified persons applying for teaching positions. In fact, a possibility exists that although the increase would probably cause more persons to apply, it might result in an actual decrease in the percentage of qualified persons and start a spiral of declining over-all quality. Much more can be done if the attitudes of the present teaching personnel are directed along proper lines.

Along the same line, it must also be remembered that increasing salaries, *per se*, will not automatically increase the effectiveness of present teachers. The problem is far more complex than such a simple philosophy would imply. A recent writer in the JOURNAL wrote facetiously, yet with an important element of truth, "Many Deans will attest that college

professors are constantly complaining about their salaries and at the same time are getting fat and sassy on them."

How frequently we hear of high school and even grade school students deciding to be a school teacher because, and only because, of the effectiveness – right attitudes if you will – of one teacher. College students are only high school students with diplomas in their hands. Here is the greatest potential source of encouragement to increase the number of engineering teachers that can be found any place–the teachers themselves. And how can we do it? You, yourself, can add immeasurably to the representative teacher attitudes that are highly desirable.

Have you ever heard the complaint that a certain person is not trying to *teach* a class, but is trying to show his own superiority by flunking in large numbers those who are assigned to his courses? In many cases the complaints are highly justified. The result is that students think, among other things, "I wouldn't want to be classified in the same profession with a character like that one." Far from being a suggestion that students should be coddled and pampered, this is a reminder that we are classified as teachers, with an active emphasis on the first syllable.

The great American tradition among students is that of complaining, whether a course is good, bad, or indifferent. There is a great difference in the tone of the complaint, however. Even a very difficult course presented with the proper exphasis will get a friendly tone of complaining. A course that is not making the student put something into it will not be so treated.

A good teacher must evidence his own interest in what he is doing by giving adequate preparation time to his courses. Interest begets interest. Proper organization of material is a necessity for good presentation. Organization requires time, and if proper time is not spent in preparation there is strong reason to suspect a deplorable lack of interest. Even so seemingly small a thing as showing the inter-relationship between various parts of a course are helpful; complete inter-relating of all the various courses in a curriculum becomes a major step forward. Interest can be markedly increased also if the instructor will eliminate any possible impression that he considers himself infallible. He isn't, and shouldn't pretend.

Negative general expressions are also bad. A particular instructor at one of our large state universities often complained to his students about the course he was teaching, his department, his college, and his university. To students' questions about why he stayed on, he replied, "I can make more money here than any place else." Such an attitude is not in any sense constructive. It can never lead to development nor improvement of the ininstructional staff, the students, or the university. This is typical of the types of things other than aptitudes which are important for teaching, and typifies wrong attitudes as well.

Attitudes toward courses include also the so-called humanistic-social subjects. Actually we need universal acceptance of the principle that "education" implies much more than narrow specialization of training. By the same token, success of cultural instruction depends to a large measure upon firm and constant support for professional faculties. Books could be written about just this last sentence.

To illustrate, a boy and his father took the same course from the same professor at times separated by a whole generation. Curiosity prompted them to compare their notes. They were amazed and the father undoubt-

edly chagrined to find the notes were practically duplicates, and that the same stories were told in the same spots in the lecture. In this field of engineering teaching there is no place for re-hashed lectures and warmed-over presentations. There are too many current items of interest that can and should be correlated into a presentation. The professor worthy of his hire should be able to add many personal-interest items based on his own experiences in research, consultation, or industrial applications. Further than that, he should have the intestinal fortitude to say "I don't know" at the proper time but not stop there. He must follow it up at a later date, if necessary, with proper comments and explanations.

In creating right attitudes much can be done too, by encouragement of cross-interest student groups. Where students see cross-interest faculty groups they soon realize that the faculty has other interests and other abilities than their own field of specialization. Emulation is inevitable. And yet an engineering instructor said to me in confidence recently, "I don't let it be known among other engineers, but I really like good music and art. I even like good poetry and literature." What a tragedy that he kept that interest so well hidden! He should be proud of it!

As An Individual

Our discussion of attitudes as an individual will be limited to those toward supervisors and associates and to those toward students. Here again the comments will be suggestive only, not all-inclusive.

One of the most difficult tasks that a supervisor, department head, or dean faces is finding a person willing to accept responsibilities. Everyone is ready to gather the acclaim and rewards, but few are willing to "stick their necks out." Some are not even willing to give or accept suggestions. Oddly enough this is too common among engineers whose very name implies ingenuity—an ability and a willingness to think. We must remember that ability to think is what we are supposed to be teaching.

Personal grudges, too, will often replace the cooperation which is a prime prerequisite to success of a group. Much can be done in this area by selecting personnel on a compatibility basis. This I cannot prove except by observing results, but in one department I am sure the head selects his staff to a large degree on the basis of how well they will get along with each other. As a result that department has an outstanding record of cooperation and loyalty that is the envy of all those looking on. Not incidentally, either, the students recognize this spirit and react in kind.

Finally, without too much elaboration we can mention a few of the things by which the instructional staff can convey to their students a real manifestation of genuinely good attitudes:

1. We must try to accept students as human beings with human emotions, ambitions, weaknesses and interests.
2. We must develop an ability to listen sympathetically and talk intelligently to students about their interests as well as their problems.
3. While it is neither necessary or right that an instructor should try to "high-hat" his students, neither should he try to be "one of the boys." Either extreme can lead to dangerous complications.
4. We must emphasize fairness and consistency in procedures without being tied to a strict routine.
5. Finally, we must develop an

ability in students to *think*, and not limit that development to the examination period.

All persons who willingly assume the responsibility of a teaching career need to prove themselves professionally competent. Beyond that competence they must have the best curriculum that can be devised with which they can work. Further still, they need to develop attitudes, insofar as they possibly can, that would do credit to Solomon in all his magnificent wisdom.

SUMMER PROGRAM ON TECHNICAL EDITING

A special summer program in Editing Technical Reports will be conducted at the Massachusetts Institute of Technology during the two weeks of September 2 to 12, 1958. Sponsored by the MIT Department of Humanities, the program is designed for technical supervisors who guide engineers and scientists engaged in technical writing, and professional editors who process formal reports for research, engineering, or development organizations.

The philosophy behind this program is that the technical editor must be a teacher as well as a writer, a psychologist as well as a critic. Comprising lectures, workshop, and seminars, the program will review practical editing procedures, analyze problems associated with writing clear, effective reports, provide supervised editing experience, and discuss problems of administration, training and report production.

Detailed information on this program can be obtained from Professor Robert R. Rathbone, Department of Humanities, MIT, Cambridge, Massachusetts.

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AN INTEGRATED CURRICULUM IN SANITARY ENGINEERING

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As a result of man's growing concern with his environment, sanitary engineering is expanding in many directions. Whereas, but a few years ago, sanitary engineering embodied only water supply and excreta disposal, it now includes water pollution, air pollution, industrial waste treatment, radiological health, and national and international public health engineering. Each year, therefore, additional responsibilities are assumed by the profession.

Curricula in sanitary engineering have reflected this expansion. Twenty years ago accepted programs consisted of courses in water supply, sewerage, water and sewage analyses, and perhaps one in public health engineering. As the field of sanitary engineering became broader, additional courses were added, each covering basic theory, analysis, and design.

In consequence, the construction of what now might be considered a typical curriculum has the shape of an inverted pyramid, more or less similar to that illustrated in Figure 1 below. The courses at the bottom of the pyramid are usually prerequisites to those above. Sewage Analyses, Water Analyses, and Public Health Engineering may or may not be part of an undergraduate option in Sanitary Engineering.

Several weaknesses are inherent in curricula of this nature. First of all, there is considerable duplication of course content. For example, sedimentation plays an important role in sewage treatment, water treatment, industrial waste treatment, and air pollution. Consequently, sedimentation is covered in four separate courses, consuming time that could be spent to better advantage on the study of additional processes. Similar duplication is found in connection with the teaching of other processes basic to sanitary engineering.

The great number of courses constituting such curricula offers certain disadvantages. Finding it impossible to take all the courses in the 9 to 12 months normally allotted to the Master of Science program, the student must elect a specialty either in sewage and industrial waste treatment, water supply, air pollution, or in some other area of sanitary engineering. Not only is the specialist limited as to initial employment opportunities, but often he also lacks the flexibility needed to grasp new technology. Furthermore, staff requirements in connection with a bulky curriculum are heavy. Where staff is limited, the only alternative to offering the courses regularly is to offer them infrequently, a procedure which reduces enrollment and, in general, weakens the graduate program of instruction.

Creative Graduates Needed

Perhaps the most serious indictment against contemporary curricula is not related to duplication or bulk, but rather to the emphasis placed on methods and practice. With a few notable exceptions, textbooks and course instruction continue to stress the empirical approach to design. Although other branches of engineer-

ing have made commendable progress in turning out creative engineers, those in sanitary engineering are in general still producing the handbook variety, a situation which imposes a serious handicap on the sanitary engineering profession.

The weaknesses outlined above have caused major concern among organizations employing sanitary engineers. As a result, considerable thought is currently being directed toward strengthening sanitary engineering curricula. Although there is lack of agreement as to just what specific changes should be made, it is generally agreed that greater emphasis should be placed on basic principles. Some schools are attempting to strengthen their curricula either by instituting one or two new courses or by making limited modifications in existing ones. A very few other schools, one of which is the Illinois Institute of Technology, have taken stronger measures toward this end.

The Illinois Institute of Technology has discarded the pyramid type of curriculum and, in its place, has adopted a totally new and different type of program. Diagrammatically, the courses constituting the core of the new curriculum appear in fig. 2.

The undergraduate sanitary engineering will ultimately consist of 9 to 12 semester credit hours course work of a nature usually required of those taking a sanitary option in civil engineering. These courses should provide a general orientation to sanitary engineering and serve as a foundation on which strong graduate work can be developed.

The four courses labeled Sanitary Sciences, Sanitary Engineering Analyses, Unit Operations and Processes in Sanitary Engineering, and Design of Sanitary Treatment Processes are to be taught at the graduate level. These courses, each carrying 4 semester credit hours, will have the following composition:

Sanitary Sciences—A lecture course covering those principles of inorganic chemistry, physical chemistry, organic chemistry, biochemistry, nuclear physics, and biological decomposition

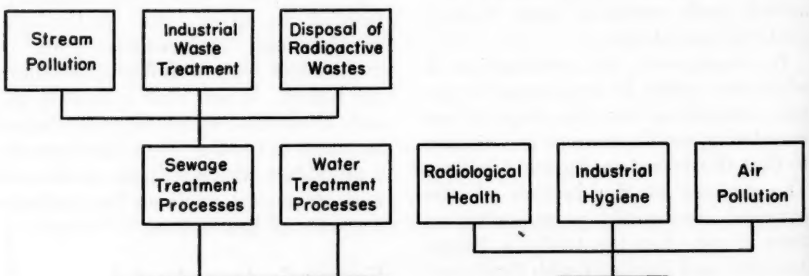


Fig. 1. Typical graduate curriculum in Sanitary Engineering.

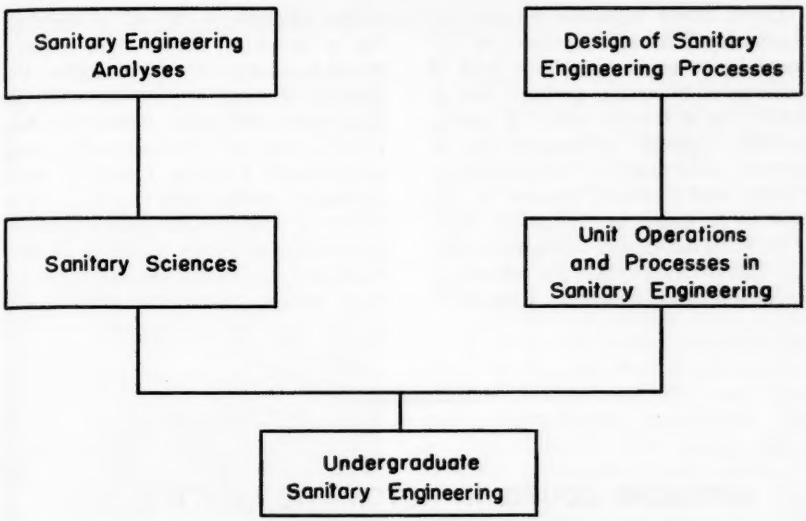

Sanitary Engineering Analyses
Design of Sanitary Engineering Processes
Sanitary Sciences
Unit Operations and Processes in Sanitary Engineering
Undergraduate Sanitary Engineering

Fig. 2. Proposed graduate curriculum in Sanitary Engineering.

which are basic to sanitary engineering analyses.

Sanitary Engineering Analyses—A lecture and laboratory course emphasizing the derivation and analysis of data for use in rational design. Prerequisite: Sanitary Sciences.

Unit Operations and Processes in Sanitary Engineering—A lecture course covering the rational design of the unit operations and unit processes employed in sanitary engineering.

Design of Sanitary Engineering Processes—A lecture and design laboratory course dealing with the application of unit operations and processes to the design of the over-all treatment processes. Prerequisites: Unit Operations and Processes.

A thesis based on laboratory research and such extradepartmental courses as Bacteriology and Statistics will fill out the normal Master of Science program.

Differences

The curriculum outlined above differs from the typical one in several respects. First, treatment processes are broken down into unit operations and processes. By so doing, duplication of material is avoided and more time is available to cover other operations and processes ordinarily not considered. This approach has been employed in chemical engineering education for several years with considerable success. Having had unit operations and processes, the student is then able to handle a much wider variety of problems in the treatment-process design course.

Second, analysis and design are taught in separate courses. Frequently, persons with backgrounds in chemistry and biology wish to obtain preparation in the analytical phases of sanitary engineering. When such is the case, they usually have no alternative but to enroll in courses in which design also is taught, a situation which may discourage and handicap the non-engineer. Under the proposed program, however, the non-engineer can select a course in which analysis only is taught.

Third, fewer separate courses are required. The student has an opportunity to cover the whole field of sanitary engineering, perhaps not in detail, but at least in terms of fundamentals. Specific techniques can be learned as he practices his profession. Finally, staff demands created by this type of program are relatively light.

Even an integrated curriculum may still fail to accomplish the objectives for which it was devised. Regardless of the advantages offered by employing a structural rather than a functional treatment of subject matter, the success of such a program will depend primarily upon where the emphasis is placed. Consequently, every opportunity must be taken to stress principles rather than practice. It is believed, however, that this emphasis, in conjunction with the type of curriculum described above, will produce truly creative sanitary engineers.

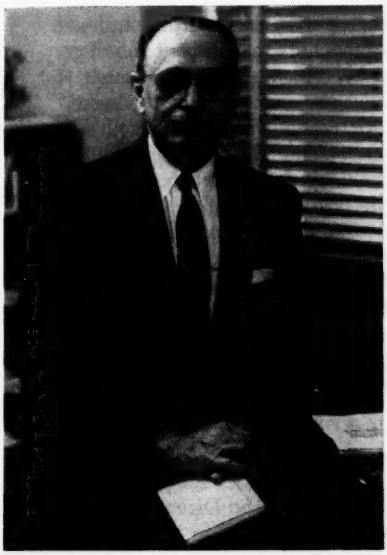
INTENSIVE COURSE IN AUTOMATIC CONTROL

The University of Michigan College of Engineering has announced a summer Intensive Course in Automatic Control scheduled for June 16 to 25, 1958, inclusive. The course is intended for engineers who wish to obtain a basic understanding of the field, but who cannot spare more than a few days for this purpose. The aim of the course is to make the subject matter easy to learn by a coherent presentation in class of the fundamentals of modern automatic control, and by providing a comprehensive set of notes which will serve as a framework for further study.

The course is built around the principles and application of measurement, communication, and control. The material will begin with the fundamentals in each of these fields and will include some basic work in nonlinear systems. This will be followed by applications of the fundamentals to more advanced problems. There will be four hours of lecture each morning and three hours of laboratory demonstration in the afternoon. Extensive use will be made of computing, instrumentation, and servo laboratories on the campus. The role of analog computing methods will be emphasized. This course has been given in the summers since 1953.

Though April 15 is the closing date for registration, further information may be obtained by writing to Professor L. L. Rauch, Room 1525 B, East Engineering Building, University of Michigan, Ann Arbor, Michigan.

KNOW YOUR ASEE OFFICERS



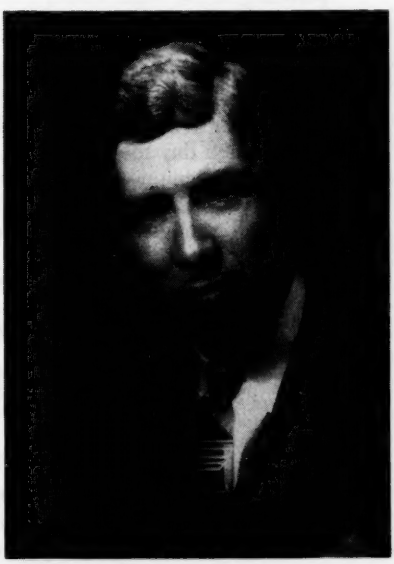
Ralph A. Morgen

DR. RALPH A. MORGEN, Vice President of ASEE for the Engineering College Administrative Council, is Director of the Purdue Research Foundation, Lafayette, Indiana. He joined ASEE in 1938 when he first accepted a professorship in chemical engineering at the University of Florida. Formerly he had held various engineering, research, and management positions in industry.

A graduate of the University of California, Berkeley, Dr. Morgen received his Ph.D. there in 1926. His career has included directorships of the Engineering and Industrial Experiment Station of the University of Florida, and of Engineering Science programs for the National Science Foundation. During World War II he served as a civilian administrator with the Office of Science Research and Development, the USAF, and the Office of Production Research and Development.

ROBERT W. VAN HOUTEN, ASEE Vice President for East Sections, is President of the Newark College of Engineering and Director of the Newark Technical School. His distinguished career in engineering education has been marked by the conferral of three honorary degrees of Doctor of Science and Engineering.

A member of ASEE since 1933, when he was an instructor at Newark, Dr. Van Houten has served on the General Council and on more than half a dozen Society committees. He is also affiliated with nearly forty business, professional, and welfare organizations. Among these are the American Council on Education, the American Society of Civil Engineers, the Association of Urban Universities, the New Jersey Association of Colleges and Universities, the New Jersey State Department of Education, and the New Jersey Society of Professional Engineers and Land Surveyors.



Robert W. Van Houten

ASEE OFFERS HELP

One of the better ways to steer prospective engineering students into engineering is to tell high school teachers more about the engineering profession. The story must be told, however, so that it is interesting to high school teachers who are concerned with the sciences, whether physical, biological, or engineering.

Because the National Science Foundation is sponsoring more than 100 summer institutes for secondary school teachers during 1958, these programs seem to offer the best chance of meeting those teachers who are interested in knowing more about the sciences and engineering. With this possibility in mind, through the cooperation of the ECAC Committee on Selection and Guidance, under the chairmanship of Mr. A. R. Hellwarth, and the counterpart committee in ECPD, under the chairmanship of Mr. L. G. Smith, an invitation and offer of assistance is being sent to each of the directors of these National Science Foundation Institutes. The letter is reprinted below:

Dear Professor ——————:

This proposal is being addressed to each of the Directors of the National Science Foundation Institutes for teachers in the fields of science and mathematics. It is a united effort of two organizations: the Engineers' Council for Professional Development, and the American Society for Engineering Education, both of which are vitally interested in the subject of vocational guidance and career planning at the high school level.

Our proposal to you is to consider in the planning of your Institute program a discussion that would relate to guidance. While teachers generally are not directly responsible for counseling, they will frequently have opportunities to provide vocational information to a class or to an individual student, both in the process of teaching and through day-to-day contacts with students. In fact, we in the profession of engineering believe that teachers of chemistry, physics, and mathematics are in a more favorable position to provide vocational information on engineering than are some other people who

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FOURTH ANNUAL AUTOMATION SEMINAR
THE PENNSYLVANIA STATE UNIVERSITY

June 9-13, 1958

Theme: "Cost Reduction Through Automation"

Contact Chester Linsky, Charge of Automation,
The Pennsylvania State University,
University Park, Pennsylvania
for further details.

have professional qualifications in guidance, but not as much background in subject matter or knowledge of opportunities in the profession and in industry. With this in mind, we hope that our proposal will provide additional background and help to the members of your Institute.

A trial program was conducted in 1957, cooperatively arranged between Western Michigan University and Mr. Gilbert P. O'Connell, State Chairman of Guidance work in Michigan for Engineers' Council for Professional Development. During one day of the Institute, an opportunity was arranged to visit an engineering laboratory, to see engineering and scientific personnel at work, to discuss questions related to guidance, and to learn about resources in the way of materials and speakers for high school student groups.

The type of program that you might plan along this line would depend on a number of factors, including the amount of time that you can devote to the subject, and to the resources available in your community. You may be able to enlist the aid of the engineering college at your campus (if there is one) or of one nearby. If not, a service is available to you through the Guidance Committee of Engineers' Council for Professional Development. If you are interested, we invite you to write to Mr. L. G. Smith, National Chairman (address below). Mr. Smith will direct your inquiry to someone locally who can help you.

Sincerely yours,

R. A. Morgen, *Vice President E.C.A.C.*
American Society for Engineering Education

copy to: L. G. Smith. E.C.P.D.
Consolidated Gas Electric Light & Power Co.
Baltimore 3, Maryland

66th ANNUAL MEETING OF ASEE

JUNE 16-20, 1958

UNIVERSITY OF CALIFORNIA

BERKELEY, CALIFORNIA

An article entitled "In and Around the College of Engineering at Berkeley" will apear in the May issue of the Journal.

REPORT OF THE COMMITTEE ON RECOGNITION AND INCENTIVES FOR GOOD TEACHING

ASEE 65th Annual Meeting, Cornell University, June, 1957

Summary of the Report

The origin of motivation and incentives for good teaching must spring from the same human drives and compensations which motivate all professional people. Teachers in our engineering schools deserve and expect opportunity, prestige and remuneration equivalent to that available from alternative professional services which they might render. Full implementation of these basic elements of motivation establishes teaching as a respected profession in our society.

Responsibility for good teaching must be shared with the teacher by college administration. The latter has an obligation to delineate specific teaching objectives and related methods for the college which are designed to advance the maturity of the student most effectively. The teacher's responsibility is discharged when he provides the most effective experiences for his students to advance their maturity and develop their creative potential within the objectives of the college.

Useful evaluation of good teaching can be made when specific objectives are defined and reasonable gradations on the evaluation scale are attempted. When acquired evidence is limited to that which the source can supply with reliability, significant evaluation of a teacher's accomplishments can be obtained from administrators, colleagues, students, and from the students' work. Data from these sources will definitely identify extremely poor teaching situations, but a question of justice will certainly be raised if an attempt is made to extend these data to reliably identify the only five teachers of a hundred who are to be recognized and rewarded for effective teaching. Sensitivity of evaluation from available data is nevertheless adequate, since a great majority of teachers should be credited with good teaching and should be recognized and compensated.

Importance of the teaching function would be placed in better perspective by creation of a national award to recognize only excellence in engineering teaching, or contribution to teaching methods, rather than administration, research, and other nonteaching activities. Institutional recognition of good teaching is intimately related to assuring adequate opportunity, prestige and remuneration to the teacher. Recognition through award of honorary professorships and financial support of teachers attending professional society meetings are samples of appreciated recognition.

A determined application by engineering colleges of procedures found successful for improving the status of the teacher will provide recognition and incentives required for good teaching.

Committee Study of Recognition and Incentives

Introduction: The Committee on Recognition and Incentives for Good Teaching of the American Society for Engineering Education was appointed in 1952 by President Woolrich. Growth of sponsored scientific and technological research within engineering colleges, and an increasing demand for college staff to serve as

industrial and government consultants, had enhanced the prestige of these activities relative to the teaching function. Educational leaders in ASEE recognized existence of a long-term trend which elevated rewards to college staff from research activity above those obtainable through devotion to teaching. The Committee on Recognition and Incentives for Good Teaching was created to investigate practices for providing recognition and incentives, and to stimulate preservation in proper perspective of the primary function of our engineering colleges.

Surveys: A survey, including committee members and other volunteers, immediately confirmed that the concern of ASEE officers for the relative prestige of the teaching function was essentially universal among educators. Correspondence left no doubt that educators could be emphatic in placing importance of the teaching function far above any other associated activity. Through contacts established by the large committee membership, data were collected on practices for recognizing and rewarding good teaching. Educator's reactions and accumulated data seemed to form discernable patterns, and confirmation of some of these was sought through a survey of deans of all ASEE member institutions. Plans for extending committee activity to regional and institutional committees have not been implemented because the wisdom of seeking manpower and modest funds for this purpose is not universally conceded.

Publications: A preliminary report of the Committee on Recognition and Incentives for Good Teaching, titled "Recognizing and Rewarding Good Teaching" was presented by R. W. Schmelzer at a general session of the 1954 Annual ASEE Meeting. This report was published in the October 1954 JOURNAL OF ENGINEERING EDUCATION. A "Report on Survey Conducted by Committee on Recognition and Incentives for Good Teaching" was presented for Harry W. Case at the 1955 Annual ASEE Meeting and published in the September 1955 *Journal.* In the October 1955 *Journal* a paper appeared by L. H. Johnson, "Ways to Improve the Status of the Good Teacher," which was also presented at the 1955 Annual Meeting. Institutional and regional reports made by members of the Committee were reproduced only in mimeograph form and are not generally available.

Basis of Motivation and Incentives

Reference to ASEE publications reveals much concern for the scope and detail of the engineering student's competence and knowledge. His teacher's personality, erudition, industrial experience, and class conduct are repeatedly and minutely scrutinized. One might expect to discover equal treatment of the human needs, drives and compensations which cause both student and teacher to fulfill his mission, but there appears to be little direct coordination expressed between these vital elements and stated objectives. This degree of neglect would be difficult to accept in an area where human attributes are as important as in the learning process if the same degree of neglect had not been evident in industry. However, recent labor demands in a competitive market have caused industrial leaders to recognize all types of human drives, including those with most powerful influence on professional people. The educational world must show similar consideration if an adequate teaching staff is to be maintained.

Opportunity: Recognition by industry of the importance of human drives and rewards other than financial is

indicated by C. H. Linder's* classification of obligations of business to the employees as:

1. "An opportunity to do good work.
2. Good facilities.
3. An appropriate reward for good performance in the form of compensation, recognition, and work security."

There is abundant evidence that college administrators have also recognized the importance of assuring their staff that their college provides opportunity through program and facilities. Possibly this has been so axiomatic of college purpose that a relative neglect has been engendered which has left the college at a disadvantage in a situation where accelerated development of social relations has occurred. Certainly there exists widespread concern that opportunity for individual's growth and reward through teaching shall equal the measure of success applied by our present social order.

Staff Evaluation of Opportunity: The teacher's evaluation of opportunity is similar to that of other professional people. The teacher's faith requires support by discernable evidence that his future and that of his family will contain desired values. The characteristic promise sought by a teacher is:

1. Opportunity to work toward known educational objectives. These must be declared by his college in sufficient detail to permit the teacher to plan and evaluate effectively.
2. Opportunity to work with competent students whose objectives are sincerely in accord with those of the college.
3. Opportunity to work with adequate classroom, laboratory and library facilities in suitable surroundings.
4. Opportunity to improve teaching conditions encountered in his work by direct experiment or by recommending related investigation and action.
5. Opportunity to belong, and to share in planning the program with confidence that his contribution is valued.
6. Opportunity to contribute to his profession in education, science, engineering or the humanities with confidence that the college applauds his activity.
7. Opportunity to work with congenial and respected colleagues.
8. Opportunity for the self-development particularly valued by young men.
9. Opportunity for the teacher and his family to live a full and enjoyable life.

Administration's Responsibility for Opportunity: Responsibility for seeking opportunity has often been conceived to belong solely to the individual who might profit. This concept is not in accord with theory and practice of modern management. Alert management is conscious that its failure to adequately define objectives, and its denial of the challenge of progress, may rob creative individuals of the opportunity to achieve their potential. A challenge exists for college administration to provide equal recognition of the true professional character of the teacher and to insure that opportunity exists for him to function creatively in his professional capacity. This opportunity can be achieved only in an atmosphere of creative activity where the attitude of administration is to fully recognize problems and to seek a cause for creating teams through which indi-

* "Obligations of Engineering Management in a Large Decentralized Company." C. H. Linder, *Electrical Engineering*, Dec. 1955.

viduals can attack the problems and contribute to progress. These activities must extend to all levels, and for all interested and creative individuals constitute an invitation.

Opportunity Through Organization: Management has recognized that the objective of creating opportunity through personnel organization is as important as the necessity to dispose of administrative chores. There are abundant problems in education to challenge personnel on all levels. An alert administration will not reserve study of these problems for top administrative officers—who seldom find time for study—but will delegate authority to as many members of their professional staff as possible. Teachers are thus assured of an opportunity for assuming responsibility, for developing their interests in education, for winning recognition, and for achieving prestige through a title associated with the task assignment.

Methods presently applied to engineering college instruction appear to some observers to have progressed little beyond the traditional methods applied to general education at the beginning of the century. Whether or not the college teaching profession has this amount of back work to do, there are certainly enough educational problems requiring continuous work to fully absorb all available personnel. A coordinating committee of the faculty can spawn fully justifiable committees to which some staff members are assigned partly as learners and to which others are assigned as experts. Most committees, or tangential subcommittees, can be restricted to a few members so individual task assignments are spread widely to encourage initiative and creativity. When teachers are denied opportunity for creative contribution to education there is danger that their talents will be diverted to an area where they are not so critically needed.

A curriculum committee may be chosen to illustrate continuing responsibility beyond an initial stipulation of class subject hours and subject titles. A need exists to continually scrutinize objectives, content, methods, and evaluation of each course, since it is truly a research project operating on the most valuable and variable of products. Although there may be instructional and evaluation committees responsible for details of implementation, the curriculum committee has an obligation to be watchful of implementation and to determine when requirements for coordination demand modification of the committee's work. Like other committees, it has an obligation to welcome written recommendations from all teachers and to respond with a sincere spirit of inquiry.

Unfavorable reaction to committees as implements for discharging executive, development, or study functions stems from administrative failures and abuses in utilizing committees. Under effective administration duties of personnel are prescribed for specific tasks to be accomplished, and committee progress or assignment of personnel is periodically reviewed for reassignment or for termination. Vague committee assignments made without time limitation, and particularly without serious expectation or provision for resulting action, have understandably led to adverse reactions toward proliferation of ineffective committees which waste everyone's time.

Student-faculty relations constitute an area where much opportunity can be created through organization. Students and faculty are involved in a continuing learning process which includes educational problems and the whole life of the college. Much benefit can be derived from joint student-

faculty study where policy decisions are to be made. When all considerations have been reviewed, necessary compromises win support until problems can be solved. The process contributes to growth of students and teachers.

Organization of groups to study the integration of student or faculty life in the college community can develop creative opportunities which lead to improved morale and greater achievement. These activities should not be left wholly to specialists, although the latter may guide study groups. Adjustment of new faculty members and students to the objectives and life of the college is a valuable and rewarding opportunity for staff members who seek this participation.

Offending distinction between the value of services rendered the college must be avoided if opportunity is to be fully developed through organization. The same levels of service should be available to teachers and should be valued equally in undergraduate, graduate, and research responsibilities.

Prestige: Much of the reward and personal satisfaction of a professional person must be derived through social consciousness. Individuals do not seek the degree of discipline and responsibility imposed by a profession unless they are strongly dedicated to service. This dedication does not appear rational unless the contribution is matched by public esteem. If teachers are to have the necessary personal conviction of the worth of their activities, the teaching function must be generally respected.

Respect for the teaching function has unquestionably been damaged by attempts within elementary, secondary, and higher education to win distinction through disproportionate emphasis on things other than the quality of teaching and learning. Campaigns to acquire research facilities and to expand the college plant have required publicity tending to focus attention on facilities. Justifiable pride in accomplishments of research and growth of the graduate schools has distracted public interest from the teacher. A resulting tendency has developed to restrict criteria for esteem to a teacher's activity in the graduate school or in research, and to exclude respect for good teaching. Prestige and dignity of the teaching function requires elevations within and without the educational fraternity.

The stature which a teacher derives from association with others in his profession is determined by the respect in which the group is held. Wherever a college creates an atmosphere of high regard for its teachers, dedicated and loyal personnel are attracted. Teachers seek and deserve recognition as professional people. A professional atmosphere is fostered when the college is careful to view its relations with the teacher as though derived from a contract for valuable services, rather than from employment to handle a required number of students for stipulated hours. Professional people treated as impersonal mass means to production feel the same forces which have turned other employee groups to collective bargaining to protect their human needs. Teachers must never be forced to turn reluctantly to alternative employment which recognizes their needs and protects their professional status and self-determination.

Association with an enterprise of distinction is small reward unless the individual is accepted as a vital part of the group. To develop a sense of belonging, the professional person requires a degree of identification with administration. The college can achieve this by assuring at least one direct two-way channel of communi-

cation between each teacher and higher administration than his immediate department head. Communication is extended to the greatest number of teachers through genuinely useful committee assignments, which should involve any teacher who does not report as an individual on areas where he may be expert. It is important to individual prestige that chanels be open to every teacher for expression of his views on college policies without reprisal and with knowledge that his recommendations are welcome.

In a group of professional people a large degree of horizontal organization is required and a vertical heirachy must be avoided. Although honor and respect may constitute a reward when derived from rank and title, the latter should not be construed to endow privilege except as privilege is generated by duty and service. Resentment is certain to be strong when communication is so attenuated that clear explanations of top administrative planning reach those who must execute the plans belatedly, if at all. Among teachers developing an educational program, progress is greatest when equal participation is not restricted by rank, whether administrative, professional, or of academic degree.

Recognition of professional status through administrative organization and award of titles achieves a satisfying level of individual prestige only when accompanied by commensurate working conditions. Although teachers are generally pleased to assist the cause of education by performing a reasonable number of subprofessional chores, a wise administration will restrict these to a minimum. When assignments must be made to non-creative committee work because there are not adequate administrative offices to discharge the work, administrators should be careful that acknowledgement of the sub-professional nature of the services and appreciation for performance are conveyed to the teacher so his prestige will not suffer.

Good teaching achieved under poor working conditions must be at the expense of individual prestige. The teacher should expect allocation to him of a suitable office, and adequate secretarial assistance should be available. Suitable laboratory and library assistants can relieve the teacher from sub-professional chores. His expenses should be budgeted and his signature honored for all expenditures within the appropriation.

Remuneration: Education in America has traditionally been subsidized in part by withholding remuneration which the teacher has rightfully earned. The public has been conscious that teacher's salaries have not constituted a fair and just compensation for services rendered. With the exception of a few periods such as the present, there have been enough scholars to staff our schools who had private resources, or who were sufficiently dedicated to ignore poverty. It is truly amazing that under the existing degree of this handicap education in America has attained such a high level. Nevertheless, its possible accomplishment has most certainly been curtailed by this attitude toward restricting motivation for good teaching.

College Attitude: That much of the public resignation toward inadequate teacher's salaries was not generated by the colleges is difficult to prove. Ambition to explore additional areas of educational service and to become big in student enrollment has led colleges to stretch their finances and perpetuate the tradition of the threadbare scholar. While the standard of living was rising about him, profoundly aided by his contribution, the

college teacher witnessed his relative financial status deteriorate and the total college budget grow with tremendous momentum. Incentive to devote a life to teaching has withered at the very time when critical need for teachers has developed. At no level is this more evident than at that of the part-time graduate teaching assistant who has traditionally been financially starved while the college was preparing him for teaching. This prospective teacher is now witness to a contradiction wherein the new graduate receives a salary in industry which is greater than that of many college teachers.

Inequities: Colleges have naturally professed greatest respect for the scholar and teacher. He is offered as the fundamental proof of the eminence of the college. Nevertheless, colleges have followed the same inconsistent path as industry in forcing professional employees to accept subprofessional pay, or to become administrators. There is little evidence that achievements of college administrators merit greater reward than can be attained by teachers. Incentive would restored to the teacher if colleges made it possible for him to receive compensation equal to that of the administrator to the highest salary levels. With improvement of professional compensation in industry, it has become critically important that disparity between the engineering teacher's college salary and that available to him elsewhere should become no greater.

Good Teaching

The broad objectives of engineering education and definitions of good teaching have been extensively investigated. The ASEE Report of the Committee on Evaluation of Engineering Education * summarizes the objectives by stating that: "Engineering Education must contribute to the development of men who can face new and difficult engineering situations with imagination and competence. Meeting such situations invariably involves both professional and social responsibilities." This same Evaluation outlines the principles of learning from the ASEE Report of The Committee on Improvement of Teaching,** which stressed "the importance of effective participation on the part of the learner; his motivation through the formulation of a goal; the clear definition of task assignments (preferably defined by the student himself); the evaluation of his progress; and his repeated practice in application." If to these definitions we add the explanation attributed to Aristotle that the objective of philosophy is "not knowledge but action," elements of good teaching can be derived through a test of their probable contribution to preparation for action.

Administration's Responsibility: Although final dependence for good teaching must rest on the teacher, responsibility for effectiveness of his work must be shared by the administration. In many instances the individual teacher has had little influence in determining facilities available, size and quality of his classes, experience of his students, and concurrent activities of his students which determine their performance and morale. Furthermore, the teacher may have had no voice in determining the pattern of objectives and approach to methods which has been established by instructional administrators. Although the teacher may have much freedom

* *Journal of Engineering Education*, Vol. 46, September 1955.

** *Journal of Engineering Education*, Vol. 43, September 1952.

to organize and administer his work within the area of the subject he teaches, he cannot be held responsible for deficiencies resulting from unfavorable teaching conditions beyond his control. Many good teachers may appear unsatisfactory in unfavorable situations.

Few engineering colleges have adequately implemented studies of correlation between their instructional practices and adaptability of students. An in-process loss of half of the students admitted to college bears witness to this neglect. Although other professional and liberal arts colleges have done no better, it is reasonable to expect colleges specializing in science and engineering to develop more commendable procedures. It has never been adequately demonstrated that the procedures through which in-process students are rejected are valid with respect to requirements of their subsequent college work, or with respect to the rate of growth required for their professional work. Design of the college curriculum, and methods within it, to cause more than half of the students to fail to meet standards of satisfactory performance has the complexion of a random operation detracting from respect for the whole college program. A teacher placed in a situation where half of his students are expected to be failures is handicapped to the point of discouragement in applying good teaching methods. Administrative procedures can certainly be devised which do not involve such a great economic loss, and which do not exact such a great price from the student and teacher.

Only when teaching objectives and methods are defined for the college with sufficient detail to permit evaluation on each subject level, does the teacher have a basis for self-evaluation of good teaching. The college cannot expect to discover a means for evaluating good teaching if no specific delineation of methods meaningful to objectives exists.

Teacher's Responsibility: As a representative of the college in direct contact with the student, it is the teacher's duty to interpret the college's objectives to the student and to report the student's response to administration. Channels for this two-way communication are often inadequately maintained.

Specific illustrations of good teaching must be related to overall objectives of the college for developing maturity of the student and to the specific program devised. Educational journals are the best source of illustrations applicable to specific situations. It is safe to generalize to the extent of observing that the objective of good teaching is not primarily to communicate knowledge, but to develop the intellectual and creative power of the student. A good teacher of engineers teaches students not only to read literature but to express and record for themselves the values derived, not only to study language but to recognize through application the power it conveys on them, not only to make mathematical manipulations but to express them as logic applied to the physical world, not only to learn the laws of science but to use them creatively, not only to learn engineering art but to develop facility in applying it to man's problems. Thereby the effective teacher assists his students to develop potential to create the wealth of tomorrow from the riches of the past.

Evaluation of Teaching

Many attempts to evaluate good teaching quantitatively have encountered difficulty because the basis for evaluation was so ambitiously broad that objectives of teaching could not be defined to produce criteria for

judging validity of the valuation instrument. Much confusion has followed relative to possible validity of evaluation of teaching made by students, staff and administrators. There is no doubt that each of these groups can perform a reliable and valid evaluation to detect teaching which is far out of line with specified objectives or practice. If these specified items are adequate for the particular purpose, evaluation is not a difficult problem. However, no reliable instrument has been devised to determine which five teachers out of a hundred should receive rewards based on relative teaching improvement for which they alone are responsible.

Everyone in contact with college education is aware that publicity credits a teacher's administrative and non-teaching activities, and undergraduate teaching least of all, as the source of his distinction and reward. It is the duty of college administration to demonstrate that this distorted perspective is not the basis for evaluating good teaching, although non-teaching activities may influence teaching. "To be effective in communicating with growing minds, the mind of the teacher must also continue to grow. Obviously anything which challenges the mind of the teacher, which causes him to work to the best of his ability in his chosen field, is not only desirable but is a necessity if we accept the truth of the preceding statement. Here then is the real role of research, of publication, and consulting in the teaching-learning situation. All of these activities demand the best efforts of the teacher; they keep his mind razor sharp; enable him to stand as an equal among his peers and thus give him confidence and self-esteem; and they enable him to bring to the classroom a wealth of current illustrative material." Students certainly derive some of the inspiration from their teachers which is required for them to undertake the self-learning process. This inspiration may be drawn from the apparent cultural and social values and realism of student experiences which the teacher designs. Opportunity exists for these experiences to be enriched from the professional accomplishments, research and enthusiasm of the teacher. To the extent that stimulation of the student is realized from these sources they constitute a justifiable basis for reward as being significant to the teaching function.

There has been some confusion in evaluating a college on the basis of its teacher's erudition rather than on that of its students. The assumption that non-teaching accomplishments are usually matched by equally distinguished teaching may be questioned. When emphasis on research proves to be non-conducive to good teaching, it should not be inferred that de-emphasis of research alone will produce good teaching. It is not unreasonable to assume that a teacher should be an authority on teaching and that his profession should be considered that of teaching. One might expect the teacher's most significant research to be in teaching, whether published or not. In many instances teaching may be considered as a continuing research activity in itself. Evidence of the value of this research should be discernible in the contribution made by the teacher to maturity of his students.

When a basis for evaluation is sought, the teacher's erudition and non-teaching accomplishments may be so very commendable that considerable care is required to assure that evaluation as a teacher is based on devotion to teaching and on the effectiveness of the teacher's contribution to growth of students.

Evaluation by Administrators: When attempts are not made to measure small differences in equality of teaching, evaluation can be made by deans and department heads whose principal responsibility it is to recognize and reward good teaching. They can easily make arrangements to have all reports, course outlines and recommendations made by the teacher available for inspection and record in his personnel file. An additional item of evidence which should be more universally used is an annual report from each teacher on the problems encountered in administering his classes and on action which he recommends. This report may be allowed to have a scope as broad as the whole life of the college.

Evaluation by Colleagues: Intellectual competence of a teacher is understandably judged with reasonable accuracy by his colleagues. Many of the qualities desirable in a teacher, but which do not insure good teaching, are evident from non-teaching activities. Why colleagues can judge the quality of teaching is not so apparent. Nevertheless, poor teaching, like crime, is difficult to conceal. Fellow teachers in contact with a teacher's students acquire a reliable impression of his extreme incompetence. In absence of this degree of poor teaching, judgment by colleagues may be distorted by impressions of non-teaching achievements, and checking with other evidence is required to establish an indication of reliability.

Evaluation by Students: The best opportunity to judge a teacher's administration of his work is available to students in his classes. Unfortunately, they are not equally well informed of the objectives and concomitant circumstances which are not under the teacher's control. If students are asked to supply evidence on items which they can observe objectively, a reliable indication of extreme conditions can be obtained. It is improbable that without other controls student evaluation will be reliable for small gradations, or valid for over-all evaluation of good teaching.

Evaluation by Examination of Students: To the extent that objectives of good teaching are measurable by examinations, existence of good teaching can be determined. Colleges which have central testing services have records available which will quickly indicate when a very abnormal teaching situation has developed. Very little further study is required to predict whether poor teaching is responsible for the condition observed. When measurements do not disclose deficiencies it must be assumed that those objectives measured are being met. In this respect, at least, teaching must be good.

When the student's work is intended to develop his maturity in areas where examinations cannot readily be devised to measure progress, the product of the student's work can be made available as evidence. To the extent that the student grows by doing creative work or being productive, the evidence of growth must appear in his work. Comparison of the product of all student's work in a teacher's class with controls from their previous classes will disclose whether experiences in the teacher's class are effective. To derive the maximum information from this evaluation it is necessary to know exactly how the class was administered, but this detail is not required to detect teaching which is far out of line with objectives.

Recognition

The teacher's fundamental human need for recognition is on the same level as that of other professional people. There is compelling necessity for recognition of the dignity and impor-

tance of the individual, which in turn requires a satisfying social status. The latter can be maintained only by remuneration for the teacher's services commensurate with his ability and professional contribution to society. Necessity exists for appreciation that compensation must be directed toward critical support of morale and must not be determined from the minimum market price and extent of sacrifice the individual is prepared to make for his profession.

Recognition of Outstanding Teachers: A valuable purpose is served by awards for distinguished service to engineering education which are comparable to those which recognize engineering service to industry or to government. It is appropriate that some awards should recognize the broadest areas of contribution to teaching, research, publications, and administration, and that these awards should come naturally toward the close of a distinguished career to men who have become publicly known as administrators. The Lamme and James H. McGraw Awards of the ASEE are of this character.

Awards which recognize outstanding contribution to the improvement of teaching, and devotion to teaching engineering students, assist in elevating the prestige of the teacher. Certainly those who have dedicated their lives to intimate implementation of the art of teaching merit acclaim as noble in its own way as that bestowed on distinguished administrators. A national award recognizing only excellence in engineering teaching, without age restriction, will be a desirable addition to the George Westinghouse Award which recognizes achievement of young engineering teachers.

Awards, which are not assignments to administrative offices, recognize faithful and commendable service to several engineering colleges. These awards provide recognition similar to that of the national awards. Extension of this recognition of an outstanding contributor to engineering education to include an appreciable number of successful teachers encounters difficulties. In a large institution, extension of outstanding awards becomes impractical because there are so many good teachers with a long period of devotion to teaching. A concept such as special named professorships is needed for recognition of good teaching on this level. Care must be exercised to base these awards primarily on teaching excellence if teaching morale is to be stimulated.

Recognition of Good Teaching: A large majority of the teachers in engineering schools are uncommonly gifted and competent people. During most of their career, recognition must be inseparably associated with opportunity, prestige and remuneration derived from the teaching function. Denial of significant aggregate recognition of the many small items contributing to these basic incentives causes personnel to move where the individual thinks he will be important and appreciated.

Removal of employment specifications, which may traditional but nonessential, constitutes an important step in creating rational criteria for recognition of good teaching. To the young man considering whether to enter or to remain in teaching, conditions which he must fulfill for recognition must not appear more encumbered with unrealistic requirements than job specifications for equal recognition in alternative professional work. Because a teacher has not obtained the traditional advanced academic degrees, it is of questionable value to withhold a professorial title when characteristically good teaching has been demonstrated. Where the level of student instruction does not require

preparation on an advanced broad technical level, there is little evidence to indicate that those holding advanced degrees have performed more good teaching than teachers not holding these degrees. Where attainment indicated by advanced degrees appears necessary, requirements for these degrees should be scrutinized to assure existence of a realistic relation to the function for which the requirements are established. Appreciation of the importance of human traits involved in principles of learning may be more significant than specialized knowledge in the humanities. An understanding of how ability to be productive and creative is developed may be more important than specialized knowledge on the frontiers of science.

Good teaching by young men can be recognized by rewards in which rights have often been reserved for administrators. Institutional financing of attendance at regional and national ASEE meetings for interested young teachers, who can least afford the expenses, can be a very constructive recognition of the importance of teaching. Only in colleges where the teaching function has not received recognition will it be discovered that the young teachers have no interest in attending such meetings. Opportunities similar to those provided by ASEE meetings exist where financial implementation can be provided for teachers to represent the college or its committees at various levels of professional societies. These opportunities for recognition will often be neglected unless the college administration seeks to develop them.

Generous support of faculty members to develop promising ideas for improving teaching is a form of recognition that will be appreciated, and one which approaches a necessity if high quality of teaching is to be maintained. This support should not be neglected through zeal to provide recognition by grants for research work. Unbalanced emphasis on research, or support of graduate school programs, can lead to a situation where teaching is considered only a necessary chore by staff attracted to the institution.

Recommendations

Survival and progress of higher education can be assured only if increased effort is expanded to:

(1) Promote the prestige and dignity of the teacher as a professional person within his institution and in the public view.

(2) Obtain compensation and contributing benefits for teaching equivalent to those available for alternative professional employment.

(3) Maintain a stimulating teaching-learning activity as the primary objective of a college.

Publicity: Conscious effort should be directed to assure that publicity through the general press and through institutional outlets should place the importance of good teaching and professional recognition of the teacher above necessary building and equipment facilities.

Written Objectives: A statement of the college's common but detailed teaching objectives should be made available to its teachers. Objectives for effectively stimulating and directing maturity of the students should be related to teaching methods which the college expects its teachers to execute.

Institutional Committee on Good Teaching: In each engineering college there should be a committee charged with responsibility for coordinating activities specifically directed toward stimulating good teaching. Support for this committee should be encouraged in a truly creative spirit which

permits the committee to function effectively.

Institutional Committee on Recognition: In large colleges a committee alert to needs of the staff for recognition and incentives can make important recommendations for improving prestige and morale of the teacher. Recognition of the teaching-learning objective of the college can be maintained.

Consultation with Teachers on Effectiveness: Communication between administrative levels should be planned to assure that each teacher has an opportunity to report periodically on the effectiveness of his teaching and to make recommendations for improvement. The communication should be reciprocal so the teacher knows he is recognized and realizes that his suggestions are received in a creative spirit.

Policy Statement on Promotion: A written statement of policy on rank and salary promotions for the teaching staff should be available to the staff at each college. This policy statement should disclose the basis for determining whether criteria have been met by the individual. It may be hoped that the policy will indicate that the earned compensation for teaching will be based only on contribution to teaching effectiveness.

Periodic Evaluation of Individual Growth: A periodic report on activities reflecting growth of each member of the teaching staff should be made to a chief executive officer of a college. The administrator responsible for assigning the teacher's duties should be required to comment on recognition accorded the teacher for his contribution to the college. It should become well known that the evaluation is used constructively by the administration to assure that merited recognition and earned compensation is not overlooked.

Recognition of Outstanding Teachers: To assist in maintaining prestige of the teaching function, creation of a national ASEE award should be considered. This award, without age restriction, should recognize distinguished service in teaching engineering students, or in contributing to teaching methods. Contributions to engineering education other than teaching should not be recognized in making this award. Colleges should consider similar institutional recognition which might take the form of honorary professorships.

ASEE Committee on Recognition and Incentives for Good Teaching: The problems associated with obtaining and holding good teachers, with maintaining morale, and with achieving good teaching are so intimately related to the interests of ECAC * that a Council committee should be charged with continuing responsibility for protecting these interests.

Conclusion

The Committee on Recognition and Incentives for Good Teaching has determined that engineering educators are aware of the necessity for improved recognition and incentives for good teaching, and it has been determined that colleges individually have made progress on the problem. There is abundant evidence that all possibilities for improvement have not been explored, and that implementation of established procedures for recognition and providing incentives has not been adequate. When engineering colleges apply with determination all the methods found desirable by individual colleges for improving the status of the teacher, notable progress will be made in restoring the teacher to his deserved professional

* Engineering College Administrative Council.

status and in demonstrating a conviction that his services are valuable and appreciated. No other course can be considered, for it is inconceivable that the American people desire to perpetrate a recognized injustice to college teachers or to jeopardize the American standard of living by permitting the quality of engineering colleges to be degraded.

The Committee on Recognition and Incentives for Good Teaching

DALE CARVER	L. H. JOHNSON	J. H. PITMAN
H. W. CASE	T. C. KAVANAUGH	C. F. SAVAGE
D. F. CORCORAN	D. R. LAMB	H. C. SPENCER
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PHILIP NUDD, *Chairman* R. W. SCHMELZER, *Chairman 1953–56*

RESEARCH INFORMATION

The Research Information Committee of the American Institute of Industrial Engineers is starting to secure abstracts of research performed in the period 1 July 1952 to 1 July 1957. Sources from which information will be solicited are universities, industrial organizations, research institutions, and non-profit organizations, including government agencies and professional societies. The information collecting program will provide a valuable service to industry and universities and especially to industrial engineers. Research abstracts are to be collected in the areas of:

WORK MEASUREMENT	INDUSTRIAL STATISTICS
METHODS	PRODUCTION CONTROL
PLANT ENGINEERING	DATA PROCESSING
HUMAN ENGINEERING	OPERATIONS RESEARCH
ENGINEERING ECONOMICS	COST ANALYSIS
ORGANIZATION PLANNING	

The committee will appreciate all information on Industrial Engineering research past and present, about which it might gather more specific details. Write:

Research Information Committee, AIIE
Department of Industrial Engineering
Washington University
St. Louis 5, Mo.

NEW MEMBERS OF ASEE

As of February 10, 1958

These applications were received in the Secretary's Office and have been duly endorsed by two members of the Society.

ASTLE, MELVIN J., Acting Dean of Graduate School, Case Institute of Technology, University Circle, Cleveland 6, Ohio. John A. Hrones; Willard E. Nudd. Divisional interest: Administrator, Educational; Chemistry.

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SARDELLA, JOSEPH E., Instructor in Drafting (Chairman), San Diego Junior College, San Diego, Cal. Frederick W. Ross, M. O. Starr. Divisional interest: Technical Institute; Engr. Drawing.

SCHRADER, GEORGE F., Assistant Professor of Mechanical Engineering, University of Illinois, Urbana, Ill. David G. Ryan, J. W. Bayne. Divisional interest: I. E.; M. E.

SINGER, MORSE B., Instructor in Mechanical Engineering, University of Illinois, Urbana, Ill. J. W. Bayne, David G. Ryan. Divisional interest: M. E.; Shop & Mech. Arts.

SMITH, JACK, Instructor in Electrical Engineering, University of Arizona, Tucson, Ariz. T. L. Martin, James C. Clark. Divisional interest: E. E.; Physics.

STEWART, MATTHEW W., Associate Professor of Civil Engineering, Polytechnic Institute of Brooklyn, Brooklyn, N. Y. Henry F. Soelinger, Chilton A. Wright. Divisional interest: C. E.

STOCK, GENE B., Instructor in Electrical Engineering, University of Arizona, Tucson, Ariz. T. L. Martin, James C. Clark. Divisional interest: E. E.

VON TURNOVICH, BRANIMIR F., Lecturer in Mechanical Engineering, University of Illinois, Urbana, Ill. K. J. Trigger, J. W. Bayne. Divisional interest: M. E.; Mechanics & Materials.

WHISENAND, JOHN L., Assistant Professor of Mechanical Engineering, University of Illinois, Urbana, Ill. David G. Ryan, J. W. Bayne. Divisional interest: M. E.

WILDE, NED, Assistant Professor of Electrical Engineering, University of Arizona, Tucson, Ariz. T. L. Martin, James C. Clark. Divisional interest: E. E.; Physics.

WRIGHT, FREDERICK D., Professor of Mining Engineering, University of Illinois, Urbana, Ill. George R. Eadie, Frank B. Lanham. Divisional interest: Mineral Technology; Mechanics & Materials.

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1. Supervision of Engineers
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3. Wage and Salary Administration

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First Week (September 7–12)

1. Psychology for Management
2. Essentials of a Retirement Program
3. Administering an Executive Development Program

Second Week (September 14–19)

4. Supervision of Engineers (Repeated)
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The Conferences will be held on the Institute campus, with enrollment limited to 22 in each of the 9 Conferences. Applicants will be admitted in the order in which requests are received.

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